RADIUM

ITS PHYSICS & THERAPEUTICS

Dawson Turner

SECOND EDITION

74.7

RADIUM

ITS PHYSICS AND THERAPEUTICS

PLATE I.

FIG. 1.—MONSIEUR CURIE.

FIG. 2.—MADAME CURIE.

RADIUM

ITS PHYSICS & THERAPEUTICS

BY

DAWSON TURNER

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PREFACE TO THE SECOND EDITION

The great advances that have been made in our knowledge of the effects and therapeutic uses of radium since the first edition of this little book was published render a second edition necessary.

The earlier portion has been carefully revised and a new chapter on the emanation of radium and on the thorium compounds has been added.

Fresh matter referring to the effect of radio-active substances on normal and pathological tissues has been inserted.

Owing to the wider knowledge of the beneficial effect of radium in the treatment of malignant disease, there is an increasing demand for its employment, from which much valuable experience has been gained. Accordingly, the section devoted to this subject has been considerably expanded, and the details of many fresh cases have been added.

As leukæmia and Graves's disease are also being favourably influenced by radium therapy, some reference has been made to this new mode of treatment in four cases of Graves's disease.

Professor Soddy has again kindly revised the disintegration series.

DAWSON TURNER.

37, George Square,
Edinburgh,
November, 1913.

PREFACE TO THE FIRST EDITION

While several works dealing with the physical phenomena of radio-activity have recently been published, and numerous articles have appeared in the medical journals upon the therapeutic uses of radium, there yet seems to be the want of a small manual suitable for medical men, which should embrace both of these topics. In this volume an attempt has been made to supply this want in a concise form.

The writings of Professor Rutherford and Professor Soddy, as well as those of Dr. Wickham, Dr. Degrais, and Dr. Dominici, have, owing to their high authority, been largely made use of throughout this work. In addition the author records his own observations founded upon a five years' experience of the use of radium as a therapeutic agent.

The author's grateful thanks are due to his colleagues in the Edinburgh Royal Infirmary, and other medical friends, for kindly permitting him to quote some of the cases treated by him for them.

DAWSON TURNER.

November, 1910.

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RADIUM:

ITS PHYSICS AND THERAPEUTICS

CHAPTER I

DISCOVERY OF RADIO-ACTIVITY—LIST OF RADIO-ACTIVE SUBSTANCES—CHARACTERISTIC EFFECTS—ALPHA RAYS

The discovery of radio-activity was made by M. Henri Becquerel in Paris in the year 1896, about a year after the memorable discovery of the X rays by Professor Röntgen in Germany. The extraordinary properties of the X rays, and their evident connection with the fluorescence of the glass of the X-ray tube, led experimenters to examine other phosphorescent or fluorescent bodies for the same type of radiation. M. Henri Becquerel in particular studied the phosphorescent substance uranium. A phosphorescent body is one which continues to glow in the dark after it has been exposed to a strong light; the luminous paint with which match-boxes are sometimes covered is an example. M. Becquerel placed a sensitive photographic plate in a light-tight envelope, covered

it with a uranium salt, and placed it outside in the sunlight; he found that the plate was affected just as though it had been exposed to the X rays, for one of the extraordinary properties of the X rays is their power of penetrating opaque bodies and of affecting photographic plates. He thus discovered that uranium when exposed to sunlight gave off a radiation akin to the X radiation. But he went farther, for one day it happened to be raining, and he placed his photographic plate with the uranium upon it inside a cupboard; on developing this plate he found it as much affected or fogged as the others which had been in the sunlight. He was not slow to see the importance of this, and he repeated the experiment, taking care that the uranium was kept in the dark all the time. The result was the same: the plate was as much affected in the dark as in the light, and neither phosphorescence nor sunlight had anything to do with it. He thus arrived at the epoch-making discovery of radio-activity. The property is an inherent one of the element uranium; it is found in all its compounds, and the radio-activity of such a compound is proportional to the amount of uranium which it contains. Thus it is an atomic property, and no chemical or physical processes to which the uranium has been subjected have so far been able in the smallest degree to affect its radio-activity. It remains the same at the heat of the electric furnace and at the cold of liquid air. Other substances were soon tested for the same proper[illegible]. Shcmidt found that thorium and its compounds, and

Debierne that actinium, were radio-active. But the most important discoveries were made by M. and Mme. Curie and M. Bémont. Mme. Curie, then a student in Professor Curie's laboratory, took up the subject of radio-activity as a thesis for her degree, and

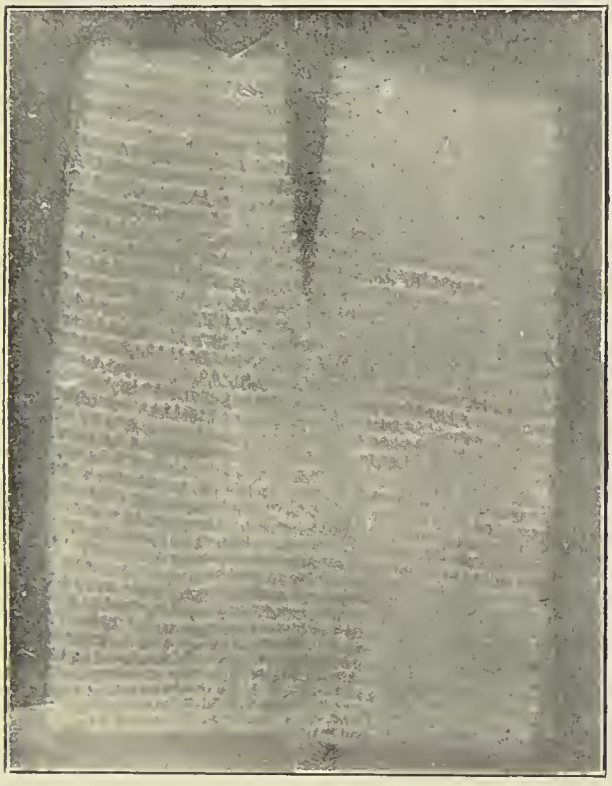


FIG. 3.—GAS-MANTLE CONTAINING THORIUM, PHOTOGRAPHED BY ITS OWN RAYS.

made quantitative measurements of the radio-activity of a large number of minerals. She found, with the assistance of Professor Curie and M. Bémont, that pitchblende and oxide of uranium were even more radio-active than uranium itself. It was evident that the ore must contain a body more highly radio-active

than uranium, and this body she set herself to isolate. The only test she had for it was its radio-active power, and the method she adopted was to endeavour by various chemical processes to separate from the ore the radio-active element. The process was a most laborious one, but ultimately a substance was obtained, though in very small quantities, which was two million times more active than uranium. At first only a tenth of a grain was obtained from 2 tons of the uranium ore, but the German chemist Giesel afterwards succeeded in extracting 4 grains from 1 ton of the best pitchblende, which is found in the celebrated Joachimsthal mine in Austria (Fig. 4). The Austrian Government very generously aided the Curies by placing several tons of pitchblende at their disposal. The new element extracted by the Curies was named Radium. It belongs to the group of the alkaline earths, and is closely allied to barium; its atomic weight was found to be 226, and its spectrum characteristic of the alkaline earths. The pure metal has recently been isolated by Mme. Curie and M. Debierne. It is white in colour, altering rapidly in air, and actively decomposing water. Its chief salts are—the bromide, chloride, nitrate, sulphate, and carbonate; the first three are soluble, the last two are insoluble. When, therefore, we speak of pure radium, we mean the pure salt, and of these the bromide is the commonest.

Radio-active Substances.—The radio-active substances separated, of reasonably slow period of trans-

formation, are—uranium, thorium, radium, actinium, ionium, and radiolead (radium D).

Of other radio-active substances of shorter life there are—polonium, radiothorium, mesothorium; in addition to these there are a large number of other substances like the radium emanation, radium A, B, C,

Fig. 4.—Pitchblende.

thorium X, and many others, which have a period of transformation measured in days or weeks. These bodies are distinguished from such substances as radium by the difference in their period of transformation and in their chemical and physical properties.

The period of an emanation means the time required for its activity to fall to half value.

All of these substances are of high atomic weight, and the value 226 places radium in the position of the third known heaviest element; uranium leading the way with an atomic weight of 238, and thorium coming next with an atomic weight of 232.

Probably there are other bodies which are radio-active;* in fact, every form of matter may be found in the future to possess this property in some degree, an atomic property as unalterable as mass, and uninfluenced by molecular combination. The dates which are important in this new line of research are as follows:

Sir W. Crookes discovered the cathode rays in 1879.
Professor Röntgen discovered the X rays in 1895.
M. H. Beequerel discovered radio-activity in 1896.
The Curies discovered radium in 1898.
Professor E. Rutherford made known his theory of atomic breakdown in 1903.

Characteristic Effects.

The four characteristic effects of radio-active bodies are—

1. They affect sensitive photographic plates in much the same manner as light.

2. They produce fluorescence — *i.e.*, they cause certain substances, such as barium platinocyanide and diamonds, to glow with a visible light.

3. They ionize the air—*i.e.*, they cause it to become

* The salts of potassium and rubidium give off beta rays.

a conductor of electricity, so that a body charged with electricity becomes discharged.

4. They produce heat.

Some of their other effects are the emission of light, the decomposition of water and various gases, the oxidation of metals in air—for this reason it is said that radium should not be preserved in an aluminium case, lest the case be eaten away by the oxidation (the writer has not observed this effect)—iodine is liberated from iodoform, glass and vitreous bodies are coloured violet, certain physiological and pathological effects are produced: these will be referred to later.

Chiefly from Professor Rutherford's work we know that these effects are due to the rays and emanation which radio-active bodies give off. The rays are divided into three kinds, known respectively as alpha, beta, and gamma rays, and each of these demands careful consideration.

The **alpha rays** are not really rays at all, but are projectiles fired out by the radium as though it were a perpetual Maxim gun. A grain of radium bromide expels each second about ten thousand million alpha particles. They each carry two unit charges of positive electricity, their mass is four times that of a hydrogen atom, their velocity is 9,000 to 13,000 miles per second, and there are conclusive reasons for believing either that they consist of helium or that they become converted into helium, that strange inert element so long known to exist in the sun, but only

recently discovered on earth. The atomic weight of the alpha particle is the same as that of helium, and Sir W. Ramsay and Mr. Soddy have found that the spectrum of helium gradually appears in a tube into which only the emanation of radium has been put. Thus is the dream of the alchemists fulfilled—there is a transmutation of one element into another: the element radium has changed into the element helium, the nobler into the baser metal, and we have the antithesis of a substance of absolutely negative properties and of very small atomic weight being produced by a substance of altogether extraordinary properties and of exceedingly high atomic weight. But this is what we might expect; the radium atom disintegrates, explodes, there is a stupendous liberation of energy, and naught but inert shattered débris remains. There are really four kinds of alpha rays, distinguished from one another by their range of penetration; but they are relatively very easily stopped, a single sheet of notepaper will intercept them, and the most penetrating type can only get through 3 inches of air and then are stopped, or, rather, cease to be detectable. It is obvious that, even if the radium be applied directly to the skin without any screen or protective covering, the alpha rays will be stopped by the outermost layer of the tissues, and therefore can only be used for the most superficial conditions. A consequence of this is that it is rarely possible to make any therapeutic use whatever of these rays, and that is to be regretted, as 95 per

cent. of the total energy of the radium resides in them.

The ionizing effect of the alpha ray is thirty times as great as that of the beta ray, but the photographic action is very small. Of their physiological action but little is known.

C. T. R. Wilson's photographs of the paths of the alpha and beta rays show that the former go straight, but that the latter are, owing to their small size, more easily deviated. The range of the alpha ray is short and definite, but is longer in a vacuum, or in an atmosphere of hydrogen.

CHAPTER II

BETA RAYS—ELECTRONS—GAMMA RAYS—PENETRATIVE POWER—MAGNETIC DEFLECTION—EMANATION—DISINTEGRATION SERIES

The **beta rays** will be best understood if a reference be first made to Crookes' experiments in 1873 and 1879. Long ago Sir W. Crookes had studied the phenomena of vacuum tubes; he succeeded in 1873 in emptying a glass tube of its air more thoroughly than had ever been done before. He brought the pressure of the residual air in the vacuum tube down to about the one-millionth of an atmosphere, and then forced a current of electricity through it. He now made the striking discovery that the electric current was transported through the tube by a shower of extremely minute particles, which, starting from the negative pole or cathode, travelled in straight lines, and caused a beautiful phosphorescent glow on the glass walls facing them. This was a true convection current of electricity, and it was travelling in the opposite direction to the currently accepted direction. Crookes called these flying electrified particles "the cathode stream," or "radiant matter," or "a fourth

state of matter." Radiant matter was prophetic, but he was ridiculed for these words.

Since Crookes' discovery our knowledge has advanced; we now call these tiny particles **electrons.** The electron is a unit of negative electricity, a disembodied charge without material substance, and its apparent mass is only the $\frac{1}{2000}$th of the mass of a hydrogen atom.

Experiments by Sir J. J. Thomson and others have shown that the beta ray of radium is, to all intents and purposes, the cathode stream of the Crookes tube. It is therefore no more a ray than the alpha ray; it consists in a stream of electrons, identical in charge and mass with those found in a Crookes tube, but travelling more rapidly. The enormous electric force at the back of the electron in the Crookes tube is quite incompetent to give it the velocity with which it is ejected from radium. The velocity of the beta particle or electron is nearly equal to that of light; it is as high as 170,000 miles a second. Owing to their great speed and small size, they have much greater powers of penetration than the alpha particle. According to Rutherford, the relative penetrating power of the three types of rays is about in the ratio 1 : 100 : 1,000. While a piece of mica or paper is sufficient to stop the alpha ray, it would take 1 centimetre of lead to insure that all the beta rays were intercepted, though most of them would be absorbed in 5 millimetres of aluminium or 1 millimetre of lead. The beta rays, like the alpha, can be subdivided into

different groups according to their range of penetration. Thus we can speak of hard and soft rays, just as we do of the Röntgen rays. They are readily deflected by a magnet. Four thousand of them would be required to balance a single alpha particle.

The **gamma ray** differs from the preceding rays chiefly in its great powers of penetration, and in its non-deflectibility by the most powerful magnetic field.

In amount as compared with the alpha and beta rays they are few; but though relatively feeble, their extraordinary powers of penetrating dense matter make them of great interest. If a fluorescent screen be placed half a metre away from a centigramme of radium in a dark room, it will be observed, by an eye which has been long enough in the dark to become sensitive, to be slightly luminous; if now a five-shilling piece be placed against the radium so as to intercept the radiation, the luminosity will be a little diminished, because those beta rays which had succeeded in reaching the screen will be cut off. All the luminosity will now be due to the gamma rays, and it will be found that the luminosity will not be diminished even if a human body be interposed between the radium and the screen.

This is not the case with the X rays; the most penetrating X rays would be robbed of much of their intensity by such a screen. For this reason radium rays are unsuitable for taking radiographs of the body; the beta rays are not penetrating enough, and the

gamma are too penetrating to throw shadows. The nature of the gamma ray is disputed; at first considered, owing to their magnetic non-deflectibility, to be a pulse or wave motion in the ether, there are now philosophers who regard them as discrete particles, but electrically neutral (positive and negative united). The question, then, is not settled. At any rate, the gamma rays are always found in company with the beta, much as the cathode ray and X ray go together. If the gamma ray is proved to be a particle instead of a wave motion, we may have to revise our views as to the nature of the X ray.

There are two chief methods of separating the alpha, beta, and gamma rays from each other:

1. By their penetrative power.
2. By their magnetic deflection.

A sheet of note-paper or 3 inches of air will cut off the alpha rays, leaving only the beta and gamma; 1 centimetre of lead will cut off the beta, leaving only the gamma.

If the rays from a radium salt are caused to traverse the space between the poles of a powerful electro-magnet, the alpha rays will be slightly bent in one direction, the beta strongly in an opposite, and the gamma not at all (Fig. 5).

If the magnet be a very powerful one, the beta rays may be bent up into spirals; the alpha rays suffer only the one-thousandth part of the deflection that the beta undergo. This magnetic analysis or

separation is not at present to be recommended as a means of separating the rays for purposes of treatment.

The **emanation,** called "Niton" (the shining one), of radium is being constantly produced, but it is only freely liberated when radium salts are dissolved in water or heated. The previously formed but imprisoned emanation can now escape. The radio-activity of

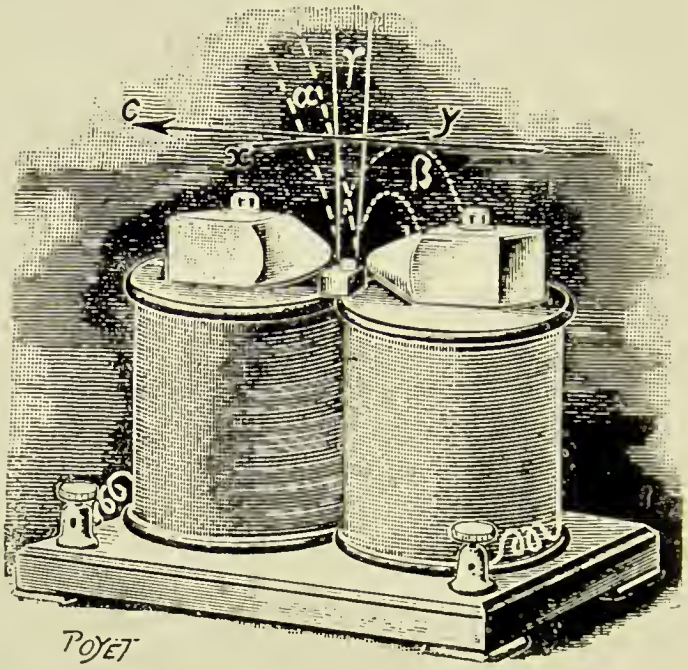


Fig. 5.—Magnetic Deflection.

radium, thus freed from its emanation, is very much reduced, but as it continues to form fresh emanation it again gathers strength until its activity is completely restored.

The emanation is intensively radio-active, mass for mass, far more so than radium itself; it gives off alpha rays at first, and then beta and gamma. Its radio-

activity does not last long; in 3·85 days it is reduced to one-half, and in about a month it has disappeared altogether. While it is losing, the radium is regaining radio-activity, and shared between the two there is a radio-active equilibrium (Fig. 6).

The emanation is a true gas which can be condensed into a liquid at −150° C.; it does not appear to have

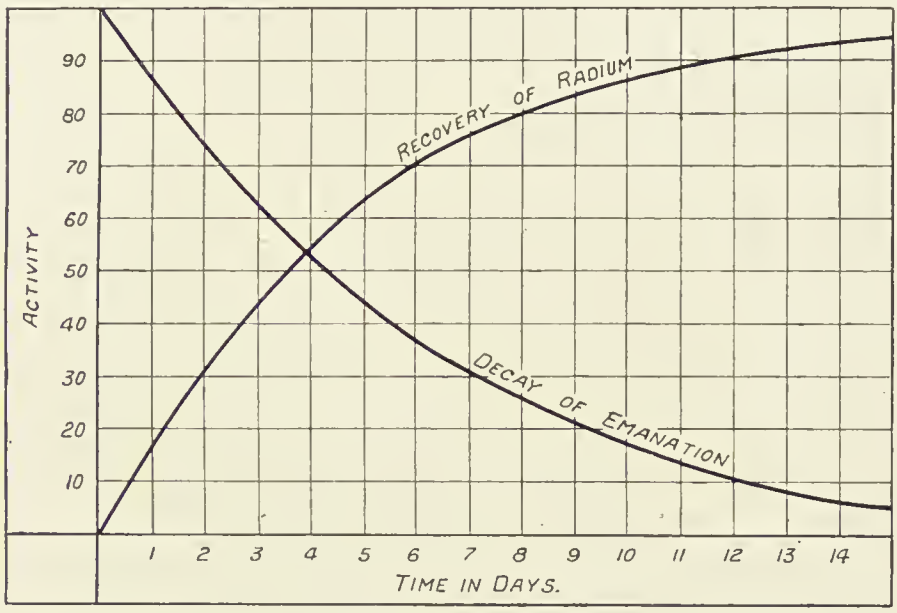
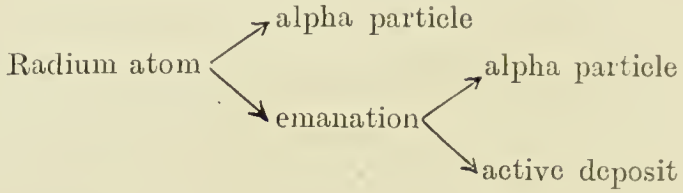


FIG. 6.—CURVE OF DECAY OF EMANATION AND OF RECOVERY OF RADIUM.

any power of entering into chemical combination or of being absorbed by any reagent; it belongs to the argon group, and is a new radio-active element. The gas is very dense, its atomic weight is 222; it is regarded as being what is left of the radium atom after an alpha particle has been discharged (Fig. 7).

The alpha particle (helium) has an atomic weight of 4; and if this number be taken from the atomic

weight of radium (226), there is left the number 222. which is the atomic weight of the emanation.



To obtain the emanation in a pure state, advantage can be taken of its property of condensing at – 150° C. A small crystal of a salt of radium is put into a small Woulff's bottle, and a few cubic centimetres of water added to dissolve the salt. If a current of air be now sent through the solution, the released emanation will be carried along with it, and if passed into a U-tube cooled by liquid air will condense in the tube in a pure state. Its presence may be well shown by introducing a little fluorescent zinc sulphide or willemite into the tube; for this will glow brilliantly when the emanation reaches it, and this luminosity will be enhanced when the emanation condenses.

A simple method of preparing the emanation for therapeutic purposes will be described later on.

Any body exposed to the emanation becomes temporarily radio-active. This induced radio-activity is produced by the active deposit of the emanation. The emanation gives off an alpha particle and changes back into a solid, the active deposit. The solid is called radium A; this in turn gives off alpha and beta particles, and changes into radium B. Radium B changes into radium C; the latter gives off alpha,

beta, and gamma rays, and changes into radium D. And so on through similar disintegrations until a body called radium G is reached. This body is believed to be lead; and that is as far as the disin-

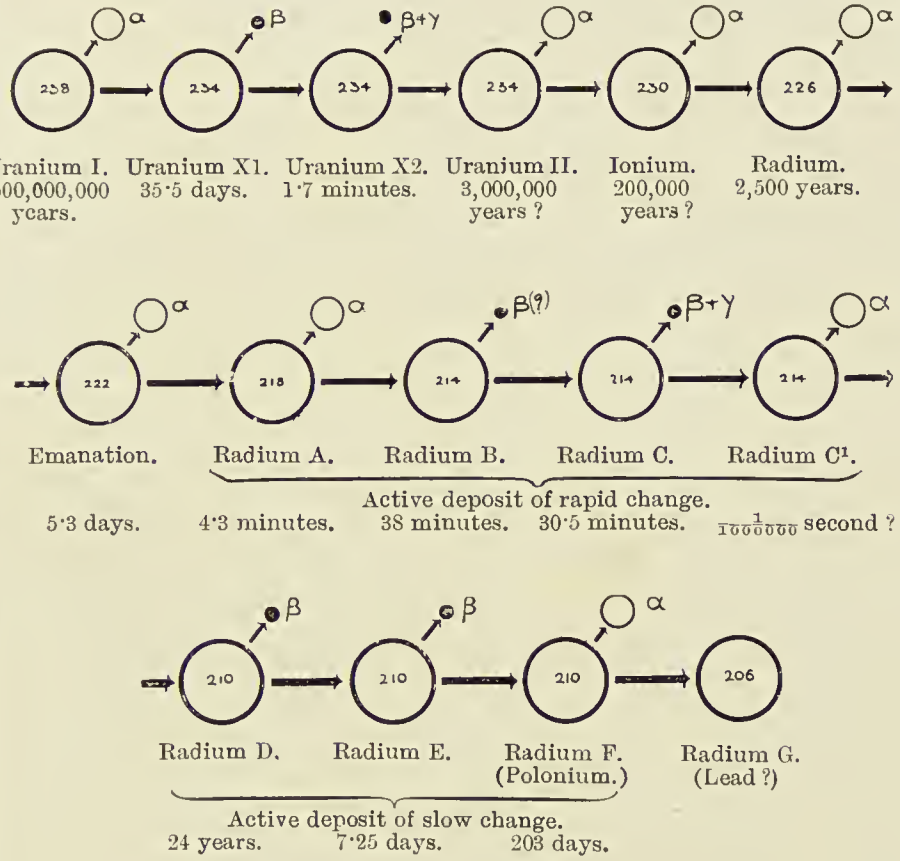


Fig. 7.—Disintegration Series (Professor Soddy).

tegration series of uranium is at present known. Radium F is the polonium discovered by Mme. Curie before the discovery of radium. Some of these changes take only a few minutes, and some take many years. One more word about the active deposit of the emana-

tion: it tends in an electric field to concentrate itself on the negative electrode; if, therefore, a needle be negatively electrified and presented to the emanation, it will become coated with practically the whole of the active deposit. This may prove of service in therapeutics.

CHAPTER III

METHODS OF CONTAINING AND APPLYING RADIUM

There are several methods of containing and applying radium. The pure salt is so valuable, 1 milligramme at present costing £18, that the greatest care must be taken to prevent any loss. In this country, the smallest usual quantity of bromide of radium sold is 5 milligrammes, put up in a small glass tube, often protected by a metal tube. This amount, 5 milligrammes, of the pure bromide is about half the size of a small pea; to examine it properly a magnifying-glass must be used. It has the appearance of raw sienna or golden-brown fragments, something like brown sugar, but not so glistening or crystalline. The freshly prepared salt is white; the colour appears after it has been kept.

The impure salt is often in the form of very small white crystals; it is commonly mixed with barium salts, from which it is very difficult to separate. The bromide and chloride are hygroscopic and soluble, and must be kept in an air-tight receptacle; this also

retains the emanation, which is of importance. The sulphate and carbonate are insoluble.

The radium is contained, for therapeutic purposes, either in—

(*a*) Sealed glass tubes;

(*b*) Ebonite capsules; or

(*c*) Mixed with varnish and spread out on pieces of cloth or metal.

(*a*) The sealed glass tube is, I think, on the whole the most convenient and useful container for general use, and where only one container is procured. It preserves the salt perfectly, retains the emanation, and can be easily cleaned and disinfected. As there is a risk of the tube breaking—either, as has been suggested, spontaneously from an electric spark, or from an accident—it should be enclosed in another tube of metal. This may be of aluminium, silver, or platinum, according to the quality of the radiation desired. The diameter and length of the tube should be as small as possible, both so as to localize the position of the salt inside and to permit of the introduction into the interior of tumours, fistulæ, etc. If the tube be longer than is necessary to hold the salt, the latter will accumulate at the end that is lowest down, a point to remember in making an application, for the effect will vary inversely with the square of the distance.

(*b*) The ebonite capsule consists of a disc of ebonite slightly cup-shaped on one side. The radium is placed in this cavity, and protected from air and moisture

by a thin mica window, which is held in position by a cap of ebonite. The radium covers a larger area than in the glass tube, and is convenient for application to superficial conditions. To contain the ebonite capsule and protect it from moisture, I have had a small aluminium box made by Baird, Lothian Street, Edinburgh, with a lid which screws on tightly enough to make a water-tight joint. The bottom of the box is

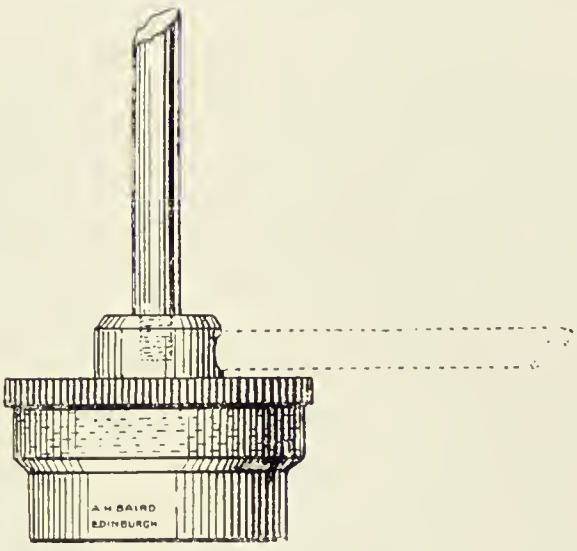


Fig. 8.—Radium Applicator.

one-fifth of a millimetre thick, so that it is practically quite transparent to the beta and gamma rays. There is a hole in the lid of the box, into which an aluminium rod can be screwed so as to facilitate applying the specimen to the interior of the mouth or other cavity (Fig. 8).

(*c*) The radium salt is mixed with hot varnish, and evenly spread on a metal or linen surface (*toile*); about 1 centigramme of the salt is allowed for each square

centimetre of surface. (The salt is usually impure.) The varnish which contains the radium is of a special kind. The metal applicator may be of copper, and of various shapes and sizes, to suit the region to which it is to be applied. On it a layer of fine metallic gauze is fixed, and into the meshes of this the radiferous varnish is run. It is by its nature stiffer than the linen applicator, and the radium is less liable to damage, but more of the alpha rays are absorbed.

The linen applicators are excessively fragile, but can be bent or folded into any shape; owing to the thin coating of varnish, the escape of alpha rays is at a maximum, but as a screen of some sort to protect the radio-active surface is almost always required, very few of the alpha rays can be utilized.

The advantage of the applicators is the great extension of the active surface. Breadth and length are increased at the expense of the thickness; thus it is eminently suitable for superficial conditions of some size—nævi, lupus, etc.—whereas with a tube a number of different applications in different spots would be required. The disadvantage is that, owing to the thinness of the radio-active layer, the beta and gamma radiation is at a minimum, and the alpha at a maximum; but the latter must be largely absorbed by the varnish, and by any screen, however thin, that may be interposed. The general result, therefore, is to weaken the effect; further, the radium is more liable to damage than when enclosed in a tube or case, so

that on the whole, in the author's opinion, this method of application is not, except in certain special cases, to be recommended.

Strength and Dose of Radium.—The first question to determine is the strength of one's preparation of radium. The French take the radio-activity of uranium as their standard, and judged by this pure radium has a radio-activity 2,000,000 times as great. If a preparation consisted of equal parts by weight of pure radium and of some other substance, its strength would be stated as equivalent to 1,000,000; if one quarter of it were radium and three-quarters impurity, its strength would be 500,000. The latter is a usual strength in France.

But it is better, surely, to state the strength simply in terms of the amount of pure anhydrous radium bromide present; thus, if the strength were said to be 10 milligrammes, it would mean that, irrespective of its total weight, the preparation contained 10 milligrammes of pure radium bromide. Commonly, the radium preparations sold in this country are purer than those in use in France.

International Radium Standard.—To meet the wishes of the Congress of Radiology and Electricity, held in Brussels in 1910, Mme. Curie has prepared a standard containing 21·99 milligrammes of pure radium chloride sealed up in a thin glass tube. In March, 1912, the Committee appointed by the Congress compared this standard with others prepared in Austria, and found a very close agreement. Mme. Curie's standard was

thereupon accepted as the international radium standard. This is to be preserved in Paris, and duplicates are to be furnished to those Governments who may require them. The National Physical Laboratory is to have charge of the British duplicate standard, and is to undertake the measurement of the strength of other specimens.

The unit of radium emanation is the "millicurie." This is the amount of emanation in equilibrium with 1 milligramme of pure radium. For measuring the radio-active strength of solutions, Professor Maché has suggested a much smaller unit, called after him the "Maché" unit. This is equivalent to the radio-activity which causes a leak of the one-thousandth of an electrostatic unit per second in a standard electrometer. Three million Maché units are equivalent to 1 millicurie—*i.e.*, one Maché unit is equivalent to the one three-millionth part of a millicurie. Three thousand Maché units are equivalent to one-thousandth of a milligramme of radium.

The radio-active strength of a preparation can be compared with that of a standard in three chief ways:

1. By the photographic effect.
2. By the fluorescent effect.
3. By the ionizing power.

The first method takes time, and does not lend itself to accurate quantitative measurement. In the second method the specimens are held in the dark at the same distance from a platino-cyanide screen, and

their relative luminosities compared; this only yields a rough guess.

The third method is the one universally adopted now. It depends on the property the radio-active bodies possess of rendering the air a conductor of electricity by producing charged carriers or ions.

If a charged body, such as an electrometer or electroscope, be approached by a specimen of radium, it will be rapidly discharged. The rate of discharge, other things being equal, depends upon the amount of radium present; hence the rate of discharge produced by the specimen is compared with that produced by a standard preparation of radium. That is the principle of the method, but various precautions must be taken and details attended to before accurate comparisons can be made (Fig. 9).

The walls of the electroscope must be of lead at least 3 millimetres thick, in order that all but the penetrating gamma rays may be absorbed, and the radium preparations to be compared must be placed in similar tubes and at exactly the same distance from the electroscope. The electric field must also be strong enough to produce saturation. To measure the activity of weak radio-active solutions such as natural waters, another method must be employed: the solution is boiled so as to expel the emanation, and the latter is introduced directly into the electroscope and the leak measured. The leak is compared with that produced by the emanation liberated by a standard radium solution.

When a specimen of radium is purchased, a written guarantee by an independent authority, such as the National Physical Laboratory, as to the amount of pure radium present should always be obtained, and the purchaser should contract to pay only according to the amount of the pure salt certified to be present.

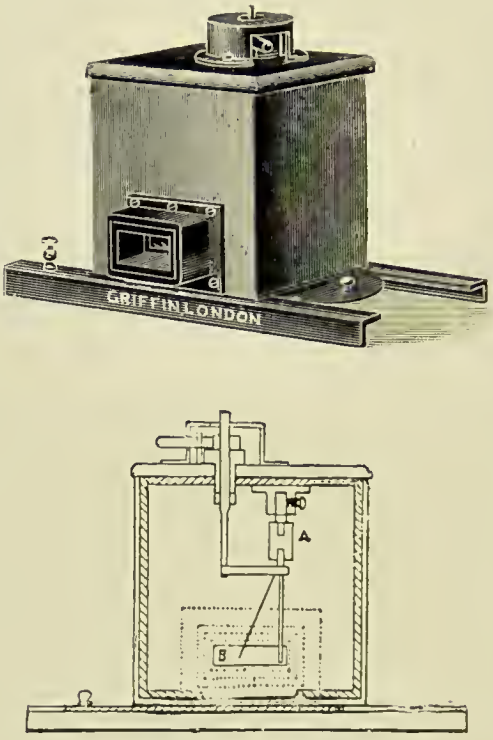


Fig. 9.—Gamma-Ray Electroscope.

When the strength of the preparation is accurately known, the dose will depend upon this strength, upon the duration of the application, the presence of screens, the age of the patient, the nature and position of the disease, etc.

The author has already suggested (*Lancet*, December 25, 1909) that the dose ought to be stated in terms

of the product of the strength of the preparation and the length of the exposure—what would be termed in an electrical measurement the "ampère hours." Thus a 10-milligramme specimen applied for one hour would be called 10 milligramme hours; applied for thirty minutes, 5 milligramme hours. If 5 milligrammes were applied for twelve minutes, it would be 1 milligramme hour, and so on. Thus a dose of 10 milligramme hours could be given by 1 milligramme applied for ten hours or 20 milligrammes for thirty minutes, etc. In this book the dosage will be so stated.

By the use of screens the radiation can be altered in quantity and quality. The effect of screens is to cut off the less penetrating rays, and so to protect the skin or superficial tissues, for only those rays which are absorbed by the skin can affect it.

All the rays of radium can be cut off except the gamma rays, and the latter are few in number. The general rule for the use of screens is as follows: If a superficial condition is to be attacked, use no screen, and give a comparatively short exposure. All the rays will now be utilized, and the effect produced will be at a maximum, especially in the immediate vicinity of the radium, because the alpha rays will predominate, and they are very powerful, but of feeble penetration. If a subcutaneous condition is to be treated, use a screen of aluminium of about half a millimetre in thickness, or a silver one of one-fifth of a millimetre, and give a longer exposure. The thicker the screen, the less

the skin will be affected, but the longer the exposure. Only the beta and gamma rays will now be of use, for a thin sheet of note-paper is sufficient to stop all the alpha rays. If the disease be still deeper, use a lead screen, one-fifth or less to 1 millimetre in thickness, and give a prolonged exposure. Only the hard beta and gamma rays will get through, and they are few in number; thus the quantity and quality of the radiation has been altered. The deeper and denser tissues will now bear the brunt of the attack, and the skin and softer tissues will be almost unaffected. Very long exposures are necessary.

Wickham and Degrais point out that, when primary rays pass through a metal such as a screen, secondary rays discovered by Sagnac are emitted. C. J. Barkla has shown that the Röntgen rays behave similarly. These rays, though of feeble penetrative power, may irritate the skin. They accordingly recommend that when a metal screen is used, a thin envelope of some non-metallic substance should in addition be interposed to cut off Sagnac's rays.

Duration of Applications.—So many considerations have to be taken into account in determining the duration of applications that it is difficult to give any precise information. Account must be taken of the age of the patient, nature and depth of the disease, strength of the radium preparation, and the presence or absence of screens.

I have found that 10 milligrammes of the pure bromide in an ebonite case with a mica window can

be applied for about thirty minutes to a capillary nævus on a baby's face, and for about fifty minutes to an adult's face, without provoking too much irritation. On the other hand, if a piece of silver 2 millimetres thick be interposed, the same specimen can be left on three or more hours; using a lead screen one or two millimetres thick, an eight hours' application can be made.

Care should be exercised as to repeating an application to a spot already treated, for it will produce far more reaction.

In some cases it may be an advantage, and in some it may be necessary, to maintain the radium at a little distance (1 to 3 centimetres) from the affected part. The result of this will be to greatly weaken the effect (it varies inversely with the square of the distance), and to extend the area of the action in the same proportion. A small piece of cotton-wool, or two or three discs of blotting-paper, or a funnel-shaped leaden cylinder, will suffice for this. This method is of service in treating a port-wine stain.

The **cross-fire method** was introduced by Wickham and Degrais, and it consists in the use of two or more specimens applied simultaneously to opposite sides of a part that it is desired to affect, so that the area between the specimens is subjected to a cross-fire. By this means, without overtaxing the skin, the interior can be exposed to a powerful radiation. Some regions are more easily so treated than others—the nose, the ear, the cheek and lip, one apparatus being

placed outside and one inside the mouth. Sometimes a specimen can be buried in a growth, and another specimen applied externally.

That **inclusion in tumours** is an extremely useful method in suitable cases I am from my own experience convinced. The tumours that are best treated by this method are those that are circumscribed and localized and of a certain magnitude. The container for the radium should be a very small glass tube

Fig. 10.—Tube and Wire for including in a Growth.

enclosed in a silver or aluminium tube with a screwed top (Fig. 10). To the silver tube should be attached a soft silver wire to anchor the tube by; the dimensions of the silver tube made by Baird, Lothian Street, Edinburgh, for me are 17 millimetres long and 3 millimetres in diameter. This tube cannot be put into a sterilizer without risk of damage to the glass tube; it is best sterilized by a formaline solution. It can be inserted by means of a trocar quite readily to any desired depth, and the silver wire can be made fast externally by surgical plaster. The thickness of the wall of the tube is half a millimetre. I will refer in a subsequent chapter to cases treated by this method.

CHAPTER IV

PRODUCTION AND USE OF THE EMANATION

To obtain the emanation from the radium, dissolve a little of the salt in water, and add a few drops of hydrochloric acid (if the salt be the chloride or bromide) to keep it in solution. The emanation released by the solution can be aspirated by a current of air into a receiver (A). For small quantities of radium the amount of hydrogen and oxygen set free need not be taken into account. A is a bottle filled with water (Fig. 11), connecting with another bottle, B, by an india-rubber tube. A is filled to the stopcock by elevating B. Then, if A is connected to the radium bottle R, as in the figure, and B is lowered, the water will fall in A, and emanation and air will be sucked in. In this way A can be filled with emanated air over water, and can then be transferred as required. After removal of the emanation a fresh quantity is produced by the radium in solution, and a supply would always be ready if the radium bottle was sealed in between; but the amount would be variable, depending upon the interval between the removals.

When large quantities of the emanation are required, it is better to use a mercury pump. Fifty milligrammes

of the bromide in solution are enclosed in a glass bulb which is connected to the mercury vacuum pump. When the pump is worked, the emanation and the hydrogen and oxygen mixed with it are drawn off and transferred over a pneumatic trough containing mercury to the containers or applicators. These may be in the form of small metallic boxes fitted with lead capillary tubes, as used at the Radium Institute, or they may be glass tubes. The applicators must first

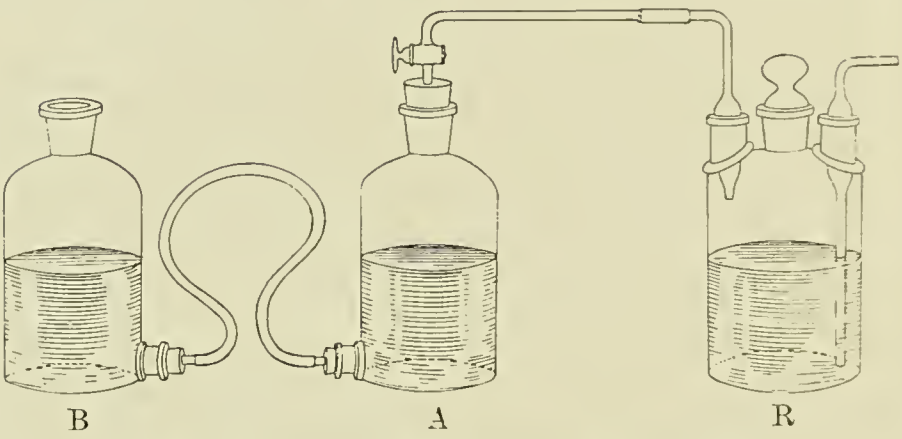


Fig. 11.—Simple Emanation Apparatus.

be pumped empty. To remove the hydrogen and oxygen, the mixed gases can be sparked before their introduction into the applicator. When filled, the applicators are closed by pincing the lead capillary tube with a pair of pliers, and by sealing the glass tubes by a blow-pipe flame.

The emanation has been used therapeutically in various ways; it has been inhaled, injected, taken in draughts, and administered by means of baths. Some natural waters are radio-active (Wiesbaden, Bath, etc.),

and their efficacy may in part be due to this. It is well known that a bottled mineral water drunk at home does not produce the same active benefit that it does when drunk fresh and nascent at the spring, and this may be due to the decay of its radio-activity. This will also explain the impossibility of successfully imitating a natural mineral water; it must be made radio-active as well as of the same chemical composition.

This can be done by shaking up the water and emanation together in a closed vessel. A certain amount of the emanation will now remain dissolved in the water. It is much more soluble in water than oxygen, its co-efficient of solubility at the ordinary temperature being 0·25. In this way more powerful radio-active solutions can be prepared than are at present known to exist naturally. One of the strongest radio-active springs known is that of Joachimstal, where the best pitchblende is found. This has a strength of 600 Maché units per litre (Saubermann, *Archives of the Roentgen Ray*, August, 1913). According to the same authority, the Silesian baths at Landec come next with 204 Maché units per litre. The Gastein springs come third, with a strength of 155 Maché units, and those at Baden-Baden fourth with a strength of 104 Maché units per litre. It is not difficult to prepare artificial radio-active water of a strength of 3,000,000 Maché units per litre. This is equivalent to 1 millicurie per litre. (The millicurie is the amount of radium emanation in equilibrium with 1 milligramme of radium.)

The emanation can be enclosed in tubes and used in place of the solid salt (Jordan, *Lancet*, December 11, 1909). It must be remembered that its activity continually decreases, being reduced to one-half in 3·85 days. Jordan aspirates the emanation into a glass tube, which he seals and encloses in a lead tube of 1 millimetre thickness; this is closed at each end and put into a rubber tube, the ends of which are closed by a silk ligature, a considerable length of silk being left attached at one end. The tube is now ready for insertion into the rectum or cervix in a case of recurrent or inoperable carcinoma. The radio-active value of the emanation tube is determined, when it is first sealed, by means of its ionizing power, and a 10-milligramme tube may be left *in situ* indefinitely. Only the gamma and hard beta rays can escape; the others are absorbed by the lead. An advantage of Jordan's method is that the loss of a tube of emanation is not of importance, but the loss of a tube of the solid salt would be very serious. A further advantage is that the whole length of the emanation tube is uniformly radio-active, while the solid crystals fall to the lowest end of the tube.

The use of the emanation in sealed tubes is not, properly speaking, the use of the emanation itself, but only of its rays and of those of the active deposit, for none of the emanation can escape; it is not in any sense comparable to the use of the emanation by injection or other introduction directly into contact with the tissues. In the latter case the emanation

tends to diffuse itself throughout the tissues; it has a predilection for the glands which form an internal secretion, and especially for the suprarenal capsules. It is eliminated by the lungs and the skin, and to a small extent by the kidneys (Bouchard, Curie, and Balthazar, Congress of Medicine, Lisbon, 1906). Injections of water or of vaseline impregnated with the emanation have been made by Radcliffe Crocker (*Medical Record*, June 12, 1909), Wickham and Degrais (*British Medical Journal*, May 21, 1910), in lupus, mycosis fungoides, and cancers, with benefit, and baths and drinks containing the emanation have been administered successfully by Strasser (*Archives of the Roentgen Ray*, No. 116, p. 332) in cases of chronic articular rheumatism, sciatica, and neuritis. Gout is also favourably influenced by this treatment.

Lowenthal (*Berlin. Klin. Woch.*, February 14, 1910) states that the emanation is chiefly absorbed by the respiratory passages, that it is of value in the treatment of chronic inflammatory processes and residues of the same, and that in therapeutic doses it is quite harmless. In order to subject the body to the permanent action of the emanation, it is necessary to apply the source of emanation several times a day, since the body gets rid of all traces through the urine and expired air within three or four hours. It is necessary in the case of baths so to construct the baths that the nose lies within the space of the bath itself, so that as much emanation may be absorbed as possible. He has found that the emanation is capable of activizing

body ferments; this action would mean that the absorbing power of the body would be increased, and in this way the beneficial action on inflammatory processes would be explained. Lowenthal comes to the conclusion that specific urate-dissolving powers are to be found in mineral waters; there may be an action whereby ferments which form and destroy uric acid may be activized by radium. It can be shown that by drinking the radium-containing waters of Baden-Baden the excretion of urea is increased by 34 per cent., while that of urates is increased by 14 per cent., as compared to the excretion when the person is drinking the same quantity of ordinary water warmed to the same temperature.

Wickham and Degrais have made an extensive use of—

1. Water rendered radio-active in the proportion of 1 milligramme of pure sulphate of radium per litre.

2. Water actually containing dissolved radium bromide of the same strength as the above.

3. Emulsions of insoluble salts of radium in paraffin and vaseline.

4. Solutions of soluble salts of radium combined with quinine, mercury, or other medicinal substance.

In all these cases the emanation is present. an element not present when the radium is enclosed in the ordinary way. In addition to the extraordinary energy of the emanation, it has been shown by Wickham that it possesses bactericidal effects on cultures of the gonococcus and staphylococcus.

More recently some valuable experiments to test the bactericidal action of radium rays have been carried out by Dr. Helen Chambers and S. Russ, and communicated by them to the Royal Society of Medicine (*Archives of the Roentgen Ray,* October, 1912). Suspensions of bacteria in distilled water instead of on nutrient media were exposed to the various rays from radium. After irradiation, measured volumes of the bacterial suspension were planted on agar, and the number of colonies which developed compared with the number from an equal volume of the control suspension. The organisms used were *Staphylococcus pyogenes aureus, Bacillus coli communis, B. pyocyaneus,* and *B. anthracis.* The main conclusion to be drawn from their observations is that the alpha and beta rays from small quantities of radium (a few milligrammes) have a distinct and direct bactericidal action. The radium rays were obtained by enclosing the bacterial suspension in a glass bulb which contained a measured volume of the radium emanation. (Quite different effects were obtained if the X rays were substituted for the emanation.) That the bactericidal action was due to the alpha and beta rays was shown by an experiment in which an emulsion of the *Staphylococcus pyogenes aureus* was exposed to the gamma rays only from 7 milligrammes of radium bromide for a week without evident effect, but when the beta rays from this source were utilized, a completely lethal effect was obtained in six hours. Their paper concludes as follows:

1. " The emanation in concentration of less than a millicurie per cubic centimetre has a marked bactericidal action.

2. " Agglutination of bacteria in distilled water is an early sequel to their irradiation.

3. " Bacteria are more quickly destroyed by the emanation than are opsonin and leucocytes."

Dr. F. L. de Verteuil (*Archives of the Roentgen Ray*, July, 1913) tested the action of radium on the lepra bacillus in a living person. Twenty milligrammes of radium bromide applied for an hour to a leprotic nodule caused within a month the destruction of every bacillus. The lepræ bacilli had been converted into a mass of small granules scattered over the field. He suggests that leprosy should be treated by saturating the body with the emanation.

The following case of large cancerous nodule of the breast treated by Wickham illustrates the use of the emulsion of an insoluble salt (*British Medical Journal*. May 21, 1910).

An emulsion of an insoluble salt of radium was made in a mixture of paraffin and vaseline. The object was to inject this preparation beneath the nodule so as to form a stratum underlying the whole of the diseased part. When this was done we applied a radium apparatus above the nodule, so that the latter had the paraffin on its under side, and the radium apparatus above, being thereby exposed to a cross-fire to which, for various reasons, we attach importance. The nodule diminished in size and dis-

appeared rapidly; there was no ulceration, and there has been no recurrence. The use of an insoluble salt prolongs the contact of the salt with the diseased tissues, and intensifies the action of the radiations and of the emanation.

The dose Wickham suggests of a soluble salt is the one-hundredth of a milligramme; these injections are perfectly supported. On the other hand, Radcliffe Crocker, who injected 2 c.c. of distilled water in which the emanation had been dissolved (radio-active strength not stated), mentions that the injections, unfortunately, several times caused painful swellings.

Dr. Saubermann and Professor Paul Lazarus have recently conducted a valuable research into the action and use of the emanation. The following remarks are taken from papers contributed by Dr. Saubermann (in which he quotes Professor Lazarus) to the meeting of the British Medical Association in Birmingham in 1911, and to the Röntgen Society on April 1, 1913:

"Radium emanation can enter the organism in several ways, but in accordance with the character of an inert gas it totally and rapidly leaves the body. The main portion leaves through the lungs, a large part through the intestines, and some through the skin and kidneys. The mode of entry decides the degree and speed of the passage of the emanation through the organism. It lasts *seconds* by inhaling, *minutes* with an injection, *hours* when taken by the mouth and stomach or *per rectum*. Consequently we distinguish five ways of absorbing emanation:

1. " Through the lungs.

2. " Through the digestive organs.

3. " Through the skin.

4. " Through the medium of different forms of injections.

5. " Through the employment of local external applications—on wounds, for instance.

" The lung is the quickest medium of absorption and discharge of the emanation. The large absorptive surface of the alveoli facilitates a direct indrawing into the circulating lung blood with each breath. Here the emanation is physically dissolved, but a chemical composition like that of carbon monoxide does not take place. The absorption is dependent on the coefficient of absorption, the temperature, and partially on the pressure. The solubility in blood is less than in water of the same temperature. The emanation penetrates from the air that is breathed into the alveolar air, from thence into the blood, and with the blood into the organs and tissue cells, which, in accordance with their specific solubility, will take up the emanation. The more regular the concentration of the emanation, the more quickly will the blood be saturated; but the moment the admission of the emanation ceases, the curve changes its direction, the emanation leaves the blood, and quickly escapes through the alveolar air. After noting that the kidneys, intestines, and skin are also the media for the excretion of the breathed-in emanation, Professor Lazarus went on to speak of the emanation

administered by the mouth through the drinking of emanation water. This entered the organism in three ways: the first, by direct penetration of the stomach and intestines; the second, by diffusion into the capillaries of the lymph and portal vein systems, the emanation circulating through the liver; the third, a method which he termed ' retrospiration,' for his tests left no doubt that a very large portion of the imbibed emanation reached the arterial blood. By inhalation the emanation reached primarily the lungs, and secondly the intestines; but the opposite took place in the drink cure. The difference between the two resided principally in the speed of the passage of the emanation through the body. Though the emanation was absorbed more rapidly in the case of primary inhalation, it would be retained scarcely as long as it was being breathed; but in the case of the drink cure the emanation was gradually introduced into the circulation, and it left the system also relatively slowly. The important feature in emanation treatment was the constant saturation of the body, which was best achieved by giving the patient a dose to drink every twenty minutes for a period of three hours. By administering ten or more doses or sips from a bottle containing the total quantity, a constant saturation of the body was maintained in a manner that would have been impossible had the total quantity been administered at once (Fig. 12). He called this form of application the ' sipping cure.' The apparatus for producing radio-active water consists of an activator—

viz., a thin porcelain cell containing an insoluble radium salt, through which the water percolates. In this manner ordinary water is rendered radio-active, and a fixed amount of radium emanation is given off each day for an indefinite number of years. The bottle consists of two parts: the lower portion, which

FIG. 12.—RADIUM EMANATION APPARATUS FOR SIPPING CURE. (RADIUM LIMITED, LONDON.)

is fitted with a tap, and the top reservoir, which contains the quantity of water which should be drunk daily."

The final portion of the paper was a description of a system evolved by Professor Lazarus and Dr. Saubermann, by which it was claimed that the inhalation of radium emanation could be rendered more efficient. The system depended upon the direct *high activation* of a respirable gas such as oxygen, and upon a closed

circuit of respiration reduced to the smallest space possible (Fig. 13). A perforated steel tube was inserted into the axis of an easily transportable steel cylinder, and filled with radium substance. The cylinder was then filled with oxygen. After four days a state of half saturation was reached. Maché units to the number of 200 to 250 per litre of oxygen were employed, and a reduction valve permitted of the exact regulation of the quantity issuing from $\frac{1}{4}$ to $\frac{1}{2}$ litre per minute. An inspiration tube led to a breathing mask, so arranged that it would close around the face air-tight, and from this an expiration tube returned through a regenerating system to the inspiration tube. In this absorber the breathed out emanation would be purified from CO_2 and H_2O vapour. In a concluding passage, after dealing with the established fact of the absorption of emanation through the intact skin, Professor Lazarus was thus quoted by his colleague:

"Emanation injections, whether intravenous, subcutaneous, or intramuscular, must prove useless, because the emanation will escape per pulmones in a very short time. Effects can only be obtained if solutions of radium salts are employed, as though establishing a kind of radium depot within the body, which can produce emanation for some time. I have practised such injections for the past six years in exudations, in joints, or in serous cavities, but always locally, and I have never been able to record a damaging effect by permanently depositing emanation within the organism."

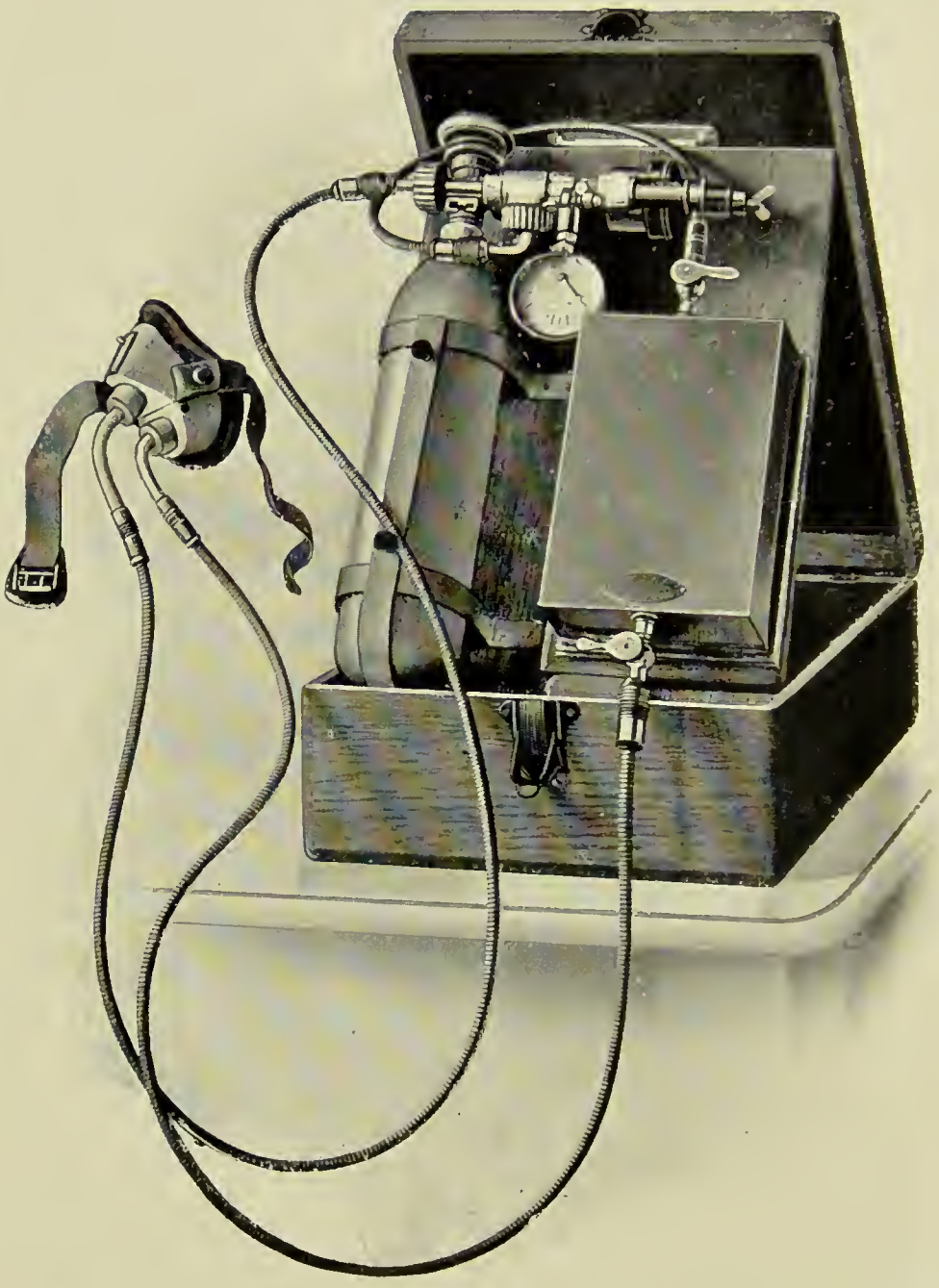


Fig. 13.—Lazarus and Saubermann's Inhalation Apparatus.
(Radium Limited, London.)

General Physiological Results obtained by the Use of the Radium Emanation.

1. " It promotes the growth of healthy cells while inimical to morbid cells.

2. " It produces diuresis.

3. " It stimulates the activity of the digestive tract, and so promotes digestion and relieves constipation.

4. " It increases the excretion of uric acid.

5. " It lowers the blood-pressure by dilating the capillaries and diminishing the viscosity of the blood.

6. " It increases the sexual activity and power of generation. Some spas—*e.g.*, Gastein and Baden-Baden—now known to be markedly radio-active have for a long time enjoyed a reputation as *rejuvenating* waters. Engelmann (*Lancet*, May 3, 1913) refers to Von Noorden's observations, and to the results of O. Hertwig's experiments, who ascertained a specific effect of radium rays on the nuclear substance of the two sexual cells, and to the observations of Halben, who succeeded in enhancing the secondary symptoms of sexual passion in water newts by radium emanation. Affections of the kidneys, tendency to bleeding, and tendency to miscarriage, are regarded at present as contra-indications.

7. " It modifies the constitution of the blood by diminishing the number of white corpuscles, and by increasing the number of red " (Saubermann, *Archives of the Roentgen Ray*, August, 1913).

Diseases for which Emanation Treatment is Suitable.

Gout, chronic articular rheumatism, gonorrhœal rheumatism, rheumatoid arthritis, neuralgias of all kinds, certain diseases of women, high blood-pressure, premature old age.

There is a general consensus of medical opinion as to the efficacy of radium emanation treatment in gout (Engelmann, Von Noorden, Lowenthal, etc.).* Treatment may combine drinking, inhalation, baths, compresses, but the most important is the *sipping* cure. The patient should every half-hour sip a dose of water containing the emanation; the total daily dose should not exceed 1,000 Maché units to begin with, but this may be gradually increased to as much as 10,000. The body will thus be kept constantly saturated with the emanation. After a few days a gouty reaction, accompanied by pains in the joints, sets in, to be followed by a slow but general improvement. Engelmann recommends a six weeks' course of treatment, which should be repeated once or twice yearly. The same general plan of treatment can be followed for the other diseases enumerated above. Engelmann, in recommending radium emanation treatment for neuritis and neuralgia, states that he has seen two extremely obstinate cases of herpes zoster in persons advanced in years, which had defied every other kind of treatment, quite surprisingly bettered. Even the

* *Vide* also p. 53.

lancinating pains of tabes are relieved (*Lancet*, May 13, 1913). The author has successfully treated an obstinate case of post-herpetic neuralgia by the radiation of solid radium. Engelmann further recommends the emanation in bronchial asthma, arterio-sclerosis, and diseases of women, especially in cases in which it is important to assist the absorption of chronic exudates and swellings; and in general adhesions, tissue thickenings of every kind cannot be otherwise than favourably influenced by a combined local and general emanation treatment. Advantageous results, he says, after radiation with radium preparations in cases of myoma and disturbances in menstruation, have quite recently been reported from the Freiburg clinic for women. In these cases the radiation with radium rays took the place of radiation with X rays. A histologically demonstrable influencing of the ovaries, and also the occurrence of miscarriage after mere drinking of emanation water, have already been experimentally ascertained. The X-ray treatment of myoma might, in the authors' opinion, be replaced by radium radiations, for the latter possess two intrinsic advantages: the dose can be measured more accurately, and the gamma rays are more penetrating. Testimony as to the value of emanation treatment in arthritis deformans is to be found in the report of the Radium Institute (*British Medical Journal*, January 25, 1913):

" This extremely obstinate, progressive, and crippling malady is not infrequently strikingly benefited by the daily drinking of 250 c.c. of radium emanation solution

of a strength of 1 to 2 millicuries per litre. The treatment must, however, be persisted in for quite a long time, and at least six weeks are likely to elapse before any change is noted. In a favourable case the articular and muscular pains are lessened or disappear, the movements of the affected joints become much freer, and are accompanied by less grating; the muscles controlling the joints regain much of their lost tone, and the general health of the patient is greatly improved. With the majority of the patients the emanation solution produces a definite diuresis, and with a few it acts as a slight laxative. Up to the present only twenty-one patients have been treated, but the results obtained are sufficient to warrant the hope that radium emanation solution will prove a most valuable addition to the routine medical treatment."

Details of six of the cases are given, and it must be noted that in one of these the patient was given 250 c.c. of radium emanation solution of a strength of 6 millicuries per litre daily for some sixty days. This is equivalent to $1\frac{1}{2}$ millicuries a day—a very strong dose. The patient was very much benefited.

The Thorium Emanation, Mesothorium, Thorium X.

The thorium emanation is given off more or less freely from the compounds of thorium, the best source, according to Professor Soddy, being a preparation of radiothorium in a moist condition.

Radiothorium is derived from thorium through two intermediate products named respectively mesothorium No. 1 and mesothorium No. 2. Mesothorium 1 is produced as a by-product in the manufacture of gas mantles; it resembles radium in its chemical nature, and cannot be separated from it; it disintegrates into mesothorium 2. The latter radiates beta and gamma rays, and yields radiothorium. From the latter thorium X is produced, and from thorium X the thorium emanation. The emanation has a life of about seventy-six seconds. It radiates alpha rays, and leaves an active deposit called thorium A. This disintegrates into thorium B, this into thorium C, and this into thorium D.

The important members of this group, from the medical point of view, are mesothorium, thorium X, and its emanation.

The presence of the emanation can be shown by its ionizing effect in discharging an electroscope, by the phosphorescence it imparts to zinc sulphide, and by its behaviour as a gas. The ionizing effect can be produced at a considerable distance, and in consequence after a certain lapse of time. At a distance of 10 feet there is a delay of about half a minute before the leaves begin to fall. When once the fall has begun, it continues steadily until the leaves are discharged. Experiments were performed by the author to ascertain whether the presence of an electrified wire gauze screen placed between the source of the emanation and the electroscope would produce any recognizable effect.

At first it appeared that when the screen was negatively electrified, the rate of discharge was accelerated and *vice versa*, the rate of discharge being three seconds when the screen was negatively electrified, five seconds when unelectrified, and ten when positively electrified. On surrounding the electroscope with an earthed conductor this difference disappeared, so that the effects previously observed must have had an electrostatic origin. A powerful magnetic field interposed between the source of the emanation and the electroscope was also found to produce no recognizable effect.

Another way of detecting the presence of the emanation is to make use of its property of making zinc sulphide phosphoresce. If a little of the emanation be blown upon a plate or through a tube coated with zinc sulphide, a very beautiful appearance will be observed—the plate will glow hither and thither wherever the emanation has impinged upon it. A puff of air by blowing the emanation away destroys the glow, which can be re-excited by more of the emanation. Professor Soddy refers in his book on the chemistry of the radio-elements to this experiment, and I had the pleasure of seeing Sir J. Mackenzie Davidson perform it.

There are various methods of preparing the active thorium compounds for therapeutic use:

1. *By Inhalation.*—Air which has been aspirated over radio-thorium contains the volatile product of thorium X—the emanation. Patients can be given this air to breathe either pure for short periods, or

mixed with ordinary air in an inhalation chamber for longer periods. A usual exposure is one of two hours in an atmosphere containing 2 to 4 Maché units per litre. In this case the medicament would enter the body by the lungs.

2. *By Ingestion.*—Thorium X can be dissolved in water, or if the emanation were aspirated very slowly through water a considerable fraction of it would be dissolved and the active deposit would be produced *in situ*. The water would contain a solution of the active deposit, and could be administered in appropriate doses.

3. *By Baths containing a Solution of Thorium X.*—It is found in bath treatment that considerable quantities of the active substance enter the body by inhalation as well as through the skin.

4. *By Local Wet Packs containing Thorium Salts.*

5. *By Injection of Radio-Active Water* either into a tumour mass or into the veins. Czerny and Caan* narrate their experiences with mesothorium and thorium X. The latter was dissolved in physiological salt solution and injected either into the growth or into the veins of persons suffering from the growths. Experiments carried out on animals showed that such procedures might easily be dangerous to life if too large doses were administered.

Thirty-six cases of tumours were treated—thirty-one carcinomas and five sarcomas. The strength of their solution of thorium X was such that 1 c.c. equalled

* *Münch. Med. Wochenschr.*, No. 14, 1912.

1 to 3 Maché units. The injections into the tumours were well borne. Twenty-four hours later a local swelling of the tumour occurred with pain and redness. This disappeared at the end of three days, and was followed by a diminution in the size, due to the gradual replacement of the cancer cells by dense connective tissue. A hæmorrhagic liquefaction sometimes took place. When the intravenous injections were employed, unexpected secondary or concomitant effects were sometimes observed, such as nausea, loss of appetite, dizziness, and weakness. No important organ suffered disturbance, nor was albumen found in the urine. The same swelling and subsequent shrinking of the tumour generally followed the intravenous injections. This seems to point to an elective action of the thorium X.

The effects produced by thorium X are due partly to the alpha rays it emits, and more particularly to the emanation of which it is the parent. The emanation spreading by diffusion conveys the action in every direction, and by disintegration coats the surrounding tissues with the active deposit, which radiates alpha, beta, and gamma rays.

Mesothorium No. 1 has been largely used of late on account of its lower cost in place of radium for the treatment of skin affections and growths, and for superficial conditions it is reported to be quite as good as, or even better than, radium. Its action must depend upon its disintegration products — mesothorium No. 2, radiothorium, thorium X, etc.—because it itself is rayless.

The thorium emanation would also probably be found of use in the same class of cases in which the radium emanation has proved of value. The class of cases referred to include gout and rheumatism and other general diseases for which natural mineral waters are prescribed. It has been found that these waters are as a rule radio-active, and that those with the smallest mineral content are the most radio-active. W. His* states that radio-active baths and waters owe their therapeutic value to the emanation of radium. After three years' experience observations have been taken on over 100 cases of gout, and the large majority have been so obviously benefited that the results cannot have been due to chance.

The emanation decomposes uric acid into urea and carbonic acid. (Mesernitsky† showed that the emanation of radium decomposed the monourate of sodium.) Lowenthal‡ states that the emanation stimulates the body ferments and increases the gaseous exchanges.

The author has only had the opportunity of trying the thorium emanation in two cases, details of which will be found in Chapter VI.; but this treatment is well worthy of an extended trial in suppurating catarrhs of the nasal cavity and frontal sinus.

* *Brit. Med. Journ.*, February 24, 1912.
† *Comptes rend.*, 1912, p. 770.
‡ *Berlin. Klin. Woch.*, February, 1910.

CHAPTER V

LOCAL EFFECT OF RADIUM ON NORMAL AND PATHOLOGICAL TISSUES

The local therapeutic use of radium is founded or based upon two chief effects which it has been found experimentally to possess:

1. A selective destructive action.
2. A general destructive action.

Effects on the Skin.—The effects on the tissues have been studied by, amongst others, Dominici and Barcat. They applied to the skin of a healthy guinea-pig a linen applicator containing 6 milligrammes of pure radium sulphate for five minutes a day for ten days. As the radium was always applied to the same spot, the dose amounted to about 5 milligramme hours.

In ten days the skin became red; in twenty an ulcer formed, over which was a crust which fell off in four to five weeks, leaving a white cicatrix, of which the skin was depigmented, hairless, smooth, and supple. If the changes in the epidermis and dermis be more closely studied, it will be found that in about ten days' time the epithelial cells of the epidermis hyper-

trophy, and that there is increased œdema. In about twenty days the epidermis is shed, and the hair follicles, sweat and sebaceous glands undergo a degeneration. In thirty or forty days the epidermis is re-formed, but the hair follicles, sweat and sebaceous glands do not reappear.

The dermis becomes in about thirty days intensely congested, and tends to pass from the adult to the embryonic condition; this is followed after a considerable interval by a return to the normal state. If the applications are too prolonged, graver changes will occur, such as necrosis of the tissues, muscles, tendons, nerves, cartilages, bones, etc.

If, on the other hand, the radium apparatus be screened by 0·5 millimetre of lead, and also by some sheets of paper and india-rubber, then it can be left on for two or three days without producing a greater effect than it produced in an hour when unscreened. Dominici calls those rays which have traversed 0·5 millimetre of lead "ultra-penetrating." They chiefly affect the deeper and denser tissues, and leave the skin and softer tissues relatively unaffected; they consist almost wholly of gamma rays. For further details reference should be made to Dominici's excellent paper in the *Archives Générales de Médecine* for July, 1909.

Effects on the Nervous System.—Danyzs, Obersteiner, Alquier, Faure-Beaulieu, London, and others, have studied this important question. The animals chosen were mice, guinea-pigs, or rabbits, and the

method of application was to insert a tube under the skin near the spine (Danyzs), or to immobilize the animal in a box in the top of which, and corresponding to the animal's cranium, was placed some radium (Obersteiner). The result of these experiments was that the animals all quickly died, particularly the young ones, from paralysis or from tonic convulsions. London observed optic neuritis in one case. In all the cases the most important and constant morbid changes were the minute hæmorrhages found in the brain and cord, and the degeneration of the endothelium of the capillaries.

More recently Sir Victor Horsley and Dr. N. S. Finzi (British Medical Association Annual Meeting, July 27, 1911) contributed a paper on the action of filtered radium rays applied directly to the brain. A platinum tube 0·5 millimetre thick, containing 27·7 milligrammes of metallic radium (Rutherford's standard) in the form of radium carbonate, was by means of a trephining operation laid directly on the pia mater over the pre- and post-central gyri of three monkeys. In another monkey a tube containing nearly double that amount was placed on the opposite side, and also on the occipital lobe. The exposures were from two and a half to four hours (about 100 milligramme hours), and the animals were killed at periods of sixteen, twenty-six, thirty-one, and forty-five days after the experiments. In none of the animals was the slightest symptom exhibited. Histologically the meninges were infiltrated with blood, and the bloodvessels showed such proliferation of their

endothelium that in some cases they were practically occluded. There was also a considerable formation of fibrous tissue which extended into the cortex and along the sulci. Further, there occurred wedge-shaped thrombotic areas in the cortex. The only change discovered in the nerve cells apart from these thrombotic areas was a condition of hyperchromatosis in the cells of the region of the cortex in which the hæmorrhages had occurred. Examined by the Marchi method, there was some degeneration of the pyramidal fibres, as well as of some fibres in the brain proceeding from the hæmorrhagic area. These experiments then confirm those of previous observers—namely, that the most constant histological changes found in nervous tissue after the application of sufficient doses of radium are vascular ones.

At the International Medical Congress held in London in August, 1913, Professor Oscar Hertwig, Dr. Lazarus Barlow, Dr. Mottram, and Dr. Russ, read important papers upon the " Effect of Radio-Active Substances on Normal and Pathological Tissues." Professor Hertwig (Berlin) said that it had been ascertained that radio-active bodies had a powerful influence on vital processes in plants and animals. The theory at first held that lecithin was the body acted on had been given up, and the microscope had shown that it was the nuclear substance that reacted to the rays. In experiments on *Rana fusca* it was found that if the spermatozoa were acted on by small doses of rays, though they did not show any perceptible alteration

in structure, yet, when they impregnated the ova, they caused an alteration in the development of the ova so as to produce "radium larvæ." This effect was produced by the rays acting on the nuclear substance of the head of the sperm cell. Many experiments on different tissues showed that while full-grown and differentiated cells and tissues were comparatively little affected, on the contrary, embryonic cells and others, which in adults lingered in an undifferentiated state, especially generative cells, young nerve cells, leucocytes, and tumour cells in a state of growth, were especially sensitive. Blood and lymph of man, and the hæmatopoietic organs connected with them were especially altered by radio-active bodies. Microscopically a great diminution of the white corpuscles was observed, caused on the one hand by wholesale disintegration, and on the other by diminution in replenishment. In the treatment of leukæmia by X and radium rays, while temporary improvement had taken place, no enduring cure had been reached. The introduction of solutions of radium and mesothorium, either subcutaneously or intravenously, had been followed by great reduction in the leucocytes, amounting almost to a leucopenia, and enlargement of the spleen and lymphatic glands had diminished.

Dr. Mottram concluded that satisfactory treatment of new growths could be expected if the cells were rapidly dividing, and there was excess of karyokinetic figures.

Dr. Russ and Miss Helen Chambers had found a wide difference in susceptibility of tumours to rays. They

had exposed such tissues to rays for varying periods, and then inoculated them into mice, and according to the duration of exposure they had obtained no growth or a slower growth in the infected animals. Furthermore, the characteristic of slow growth assumed by these irradiated tumours had been transmitted to successive generations, confirming the work of the French school.

A new departure was made by Dr. W. S. Lazarus Barlow and his pupils, who had investigated the question of very small amounts of radium (around the order of the one ten-millionth of a milligramme), since Dr. Barlow had found small quantities of the element in cancerous tissue. His researches had shown that the mean quantity of radio-active substance in a variety of normal tissues was the one thousand-millionth of a milligramme per 100 grammes of tissue. On the other hand, in the non-malignant tissues of cancerous individuals, the mean quantity found was twenty-three times as great, and in actual cancerous tissue the mean was not less than fifty-one times as great. Dr. Barlow had examined the effect of quantities of radium of the order of magnitude under consideration upon the development of the ova of *Ascaris megalocephala*, and had found clear proof that in these very small quantities radium stimulated the division of cells. He concluded by expressing the opinion that radium treatment was a possible treatment of cancer, but only when used in sufficient strength to kill the cancer cells and stimulate the connective tissue cells.

Effect on the Liver.—Dr. Mills (*Lancet*, August 13, 1910) studied the action of the gamma rays on the liver of mice. The applicator used was one of 500,000 units, and it was guarded by a shield which cut off the alpha and beta rays, while allowing the gamma rays to pass through. It was applied to the anterior abdominal wall for thirty minutes in each case. (This is not explicit as regards the dose unless the weight of the salt used be added.) The mice were killed at varying intervals after exposure, and the liver examined microscopically.

The effect, briefly, on mouse liver was found to be as follows:

1. Within an hour after irradiation a transient change had commenced in the liver cells, somewhat resembling "cloudy swelling."

2. There is an early inflammatory reaction, lasting a few days.

3. There is a late inflammatory reaction, coming on in about fourteen days and lasting much longer. This was confined to the connective-tissue elements, and consisted of a marked general infiltration of the liver with lymphocytes, connective-tissue cells, and a few polymorphonuclear leucocytes, and this to a greater extent than in any of the sections taken during the few days immediately following irradiation. These changes were associated with a general hyperæmia. This, the probable histological basis of the radium reaction, is confined to the connective-tissue elements.

Effect on the Human Tissues.—If an unscreened

specimen of radium be applied in a sufficient dose to the healthy skin, there will be observed in the course of twenty-four hours to a few days a red spot, which will become slightly raised and a little tender. A few flakes of epithelium may separate, and over this a scab may form, resembling, as Wickham has pointed out, an impetigo crust; this may persist for a time, or be replaced by another, but it will finally fall off, leaving fresh, soft, supple skin beneath it.

If the dose be too strong an ulcer will form, which will discharge, become covered with crusts, and may finally leave a white, atrophic, depressed scar. Sometimes telangiectases follow. I have not observed any tendency to form the obstinate and painful X-ray sore.

There are certain positions in which the effect of radium is more marked. The lower eyelid, in consequence partly of the looseness of the tissues, is very easily affected and swells, and exposures there should be short. Any exposure in the neighbourhood of the eye is very liable to produce a marked congestion of the conjunctiva; this will pass away without trouble. The nasal and buccal mucous membranes are also very sensitive. When a reaction has been produced and has passed away, care must be taken not to repeat the application to the same spot for a couple of months, for the part will be found to be extra sensitive, and unpleasant results may follow.

Thus the effect of radium is cumulative.

The histological changes produced in malignant growths by radium have been studied by Dominici,

Rubens-Duval, Barcat and Faure-Beaulieu (*Arch. Gén. de Méd.*, July, 1909). In the case of lymph-adenomas, the free lymphatic cells are destroyed, while the stroma undergoes sclerosis.

In the case of sarcomas, the embryonic tissue becomes converted into fibrous tissue, and the blood-vessels wither and dry up; a malignant tumour formed of embryonic tissue becomes converted into a fibroma, a benign tumour consisting of fibrous tissue. The latter undergoes retrogressive changes and shrinks, and a cure is thus brought about.

In the case of epitheliomas and carcinomas, the cancerous tissue is in part destroyed, and in part has its evolution arrested.

These are, briefly, the changes which may be looked for in growths whose evolution is arrested by radium.

Mr. Gilbert Barling, in his address in Surgery (*Brit. Med. Journ.*, July 30, 1910), makes the following remarks as to the action of radium on malignant disease, and the histological changes produced:

" Immunization by radium has a special interest. If a portion of mouse carcinoma be exposed to the action of radium for a period insufficient to produce any structural change, gross or microscopic, and this fragment be subsequently inoculated into other mice, the inoculation fails, no growth takes place. In mouse carcinoma which has already been established by inoculation, exposure to radium causes some of the tumours to disappear; others continue to develop normally, and a few, perhaps, flourish more actively.

"Sections taken from the disappearing tumours may show hæmorrhages, but the most noticeable change is an active proliferation of the connective tissues, especially at the margin, and an invasion of the parenchyma of the tumours by young fibroblasts. As these complete their development, they contract on, strangle, and destroy the epithelial cells they embrace. We have no evidence here of a direct specific effect on the epithelium of the growth, which is found to be still actively proliferating. We have, then, after the application of radium to implanted carcinoma, a formation of scar tissue. Further experiments with radium have shown that cure of an inoculated growth exposed to its rays gives immunity to subsequent inoculations of carcinoma. This immunity is not confined to the particular area involved by the tumour, but extends to the whole body. The quality of immunity thus induced may have its value in increasing the resistance of the body when once a process of cicatrization of a malignant growth has been set up in the human tissues by treatment with radium.

"Turning to radio-therapy, we can immediately accept radium as curative in rodent ulcer, with this reservation, that the permanence of cure must be certified by a longer period of time than has yet elapsed in most of the cases treated. If we scrutinize the results of treating growths which are undoubtedly malignant, as shown by progressive local invasion and by secondary formations in lymphatic glands or other parts, we find much that is promising, but little

that is conclusive. A profound impression is produced in many instances; malignant tumours of large extent and depth may disappear or much diminish. But the improvement and the apparent recovery is apt to be deceptive, and the subsequent return of the growth, which progresses to the death of the patient, appears to be a not infrequent experience. If a patient is the subject of an inoperable tumour, we are grateful for the benefit radium may give in the relief of pain, in the cessation of discharge, in the cicatrization of an open sore, and we should rejoice if cure seems probable. But when called upon to treat patients with operable malignant growths, are we justified in advancing radium as a substitute for excision? Personally I would not at present take this responsibility."

These remarks, coming from a surgeon of great experience, and who is without bias in favour of radio-active methods, are of great value.

Radium has, as already mentioned, a selective destructive as well as a general destructive action, and it is the former action which gives it its chief value. In its power of selection it takes complete precedence of other caustics; this, added to its extraordinary powers of penetration, enables it to seek out and destroy elements to which it is inimical—*e.g.*, neoplasms, angiomas, etc. — while passing by and leaving unharmed the normal tissues. To this must be attributed the excellent scars left by radium treatment.

CHAPTER VI

CHIEF DISEASES IN WHICH RADIUM MAY BE USED

The chief diseases in which radium has proved of service are as follows: Rodent ulcer, angiomas, warty growths, lymphadenomas, malignant growths, leucoplakia, lupus erythematosus, lupus vulgaris, cheloids, Graves' disease, neuritis and neuralgia, tubercular glands, spring catarrh, corneal ulcers, pruritus, syringomyelia. The emanation has been used (p. 46) in gout, in simple and gonorrhœal rheumatism, in rheumatoid arthritis, in neuralgia, and in catarrhal affections of the respiratory tract. In France they prefer to use it in baths and in poultices containing radiferous substances; in Germany they administer it by ingestion and inhalation.

Of all serious diseases, rodent ulcer is the one that is the most amenable to radium treatment. The experience of many cases has taught me that in superficial or deep rodents not situated on mucous membranes, provided the bone and cartilages are not affected, radium properly applied acts as a charm. The latter is quite a proper term, for under the influ-

ence of radium, without any operation, bleeding, suffering, or even discomfort, the hard edges of a rodent will melt down, the surface will fill up, and there will be a complete *restitutio ad integrum*. The reason why radium is so superior to carbonic snow, zinc ionization, or excision, is, firstly, because the rays penetrate so deeply—in fact, right through the body (the gamma rays will penetrate 10 inches of lead)—so that the very roots of the disease are attacked; secondly, the treatment is absolutely painless; thirdly, the cosmetic result leaves nothing to be desired. Captain Pinch, in charge of the Radium Institute, points out in the Annual Report of the Institute that many of those rodent ulcers which have received treatment for a long time with X rays, zinc ionization, carbonic snow, etc., respond badly to radium treatment, and it is unwise to make any pronouncement as to the probable result. Quite frequently the previously treated tissues break down to an extent which far exceeds the existing ulceration, and repair is very slow and imperfect. More than half of the cases of rodent ulcer which applied for treatment at the Radium Institute were of this character, and the destruction of tissues was so great that no hope of satisfactory repair could be entertained.

As a rule, beyond what is necessary to protect the radium, no shield is required. The use of a shield would prolong the treatment without corresponding advantage. If the radium is in a glass tube, apply it directly to the surface of the ulcer, and fix it in position

by a strip or two of plaster. The patient, if the ulcer is on the face, should be recumbent. See that the tube is so placed that its lowest end is against the ulcer, as the radium will naturally gravitate to that end. If the radium is in a capsule with a mica window, wrap a thin piece of india-rubber round the capsule, and apply it directly to the ulcer.

If the area of the ulcer be greater than th active surface of the radium, successive applications must be made in different places until the whole has had a sufficient dose. Or the radium may be supported upon some cotton-wool at a little distance (a few millimetres) from the surface of the ulcer; this will extend the area of the radio-active effect, but diminish its intensity, so that longer exposures will be necessary. If the rodent be near the eye, the latter must be protected by a shield of lead-foil; if in spite of this a conjunctivitis be set up, no anxiety need be felt, for the inflammation will be transient. What dose should be given ? That depends upon the position, duration, and depth, of the ulcer, the age of the patient, etc., but for a superficial rodent on the nose you may begin by a dose of 20 milligramme hours for each position—that is, the application of 10 milligrammes of pure radium bromide for two hours, or what is equivalent to that (*vide* p. 27). After the whole area of the ulcer has received this dose, interrupt the treatment for four to six weeks or longer, and then recommence, being guided by the effect already produced.

If the ulcer be deeper and more serious, give longer

exposures without waiting to see the effect. Remove all scabs and clean the surface before applying the radium.

After-Treatment.—This is simple. As a rule no after-dressings are necessary; leave the part alone. If the surface be suppurating, wash with a mild antiseptic several times a day. If it be dry and itchy, apply a soothing ointment. If possible, do not interfere with the scabs which will form; in three to six weeks' time, when they come off, the surface wil probably be healed.

Now to refer to some of the cases I have treated.

Case 1.—A male, aged forty-six years, consulted me in 1906; he was suffering from a rodent ulcer on the nose. It was of the size of a sixpence, punched out, and of about a year's duration. He was treated by the X rays, applied two or three times a week for about three months, but without much benefit. Radium was now tried, and eighteen applications of twenty minutes each (six hours in all) caused it to heal over with a soft, supple scar. In this case 5 milligrammes of impure radium bromide of an activity of 300,000 were used. Expressed in proper terms, the dose was about 4·25 milligramme hours. He has since had, at intervals of about six months, three recurrences, each of which has yielded at once to one or two fresh applications. He is a working man who cannot afford the time to have it thoroughly treated, but he has now had no recurrence for five years.

Case 2.—A patient, aged about fifty years, recom-

mended to me by Dr. M. Burnett, consulted me about a rodent ulcer of six years' duration, placed close to and invading the inner canthus of the eye. It was a little smaller than a sixpence. I shielded the eye with lead-foil, and gave him in all five hours' treatment with 10 milligrammes of pure radium bromide (50 milligramme hours); no shield except a thin piece of parchment paper was used. In one month's time he was completely cured, and there has so far (four years) been no recurrence. This case and the preceding one illustrate the necessity for pushing the treatment beyond what would otherwise seem to be required, if a recurrence is to be avoided.

Case 3.—A more serious case, in an older gentleman, recommended to me by Dr. G. Carmichael. The ulcer measured $2\frac{1}{2}$ by $1\frac{3}{4}$ inches, was excavated, had very prominent raised edges, and extended from the nose to the inner canthus. It was of many years' duration. It was treated with 10 milligrammes of pure radium bromide, enclosed in an aluminium box one-fifth of a millimetre thick, for four hours weekly. Improvement was slow but steady, and now, after a total of eighteen hours' exposure (180 milligramme hours), the ulcer is completely healed, and covered with a beautifully supple skin. The actual treatment occupied about six weeks, but the full improvement was not noticeable until many months had elapsed. This was a large ulcer to attack with a radiating surface of radium of only 1 centimetre in diameter; each application was made to a different spot until all had been treated, when

they were re-exposed. In Paris they would, no doubt, have treated this case with a radium plaster, so as to attack its whole surface at once; but, as I have already explained in a previous chapter (Chapter III.), the density of the radiation would have been much weaker, and I doubt whether a quicker result would have been obtained than by my method of applying the whole quantity to a small area at a time.

Case 4.—A gentleman, aged seventy-six, recommended by Dr. George Mackay. The patient suffered from a rodent ulcer which had partially destroyed the inner canthus of the left eye, and was extending along the lower border. It was of twenty-three years' duration, had been burnt four times, and was now extending rapidly (Fig. 14). After a photograph had been taken, treatment with radium was begun. The eye having been protected by a piece of lead, 10 milligrammes of the pure bromide were applied in an aluminium box directly to the surface of the ulcer. The rays had to traverse a mica window and a piece of aluminium one-fifth of a millimetre thick. This was in May; improvement began at once, and in two months' time, after fourteen and a half hours' exposure (total 145 milligramme hours), the ulcer was healed. Another photograph was now taken (Fig. 15). This serious case affords an example of the rapidity with which radium can act in suitable conditions. The scar tissue will continue to improve for some time.

During the year 1912 eleven rodents were treated by radium in the Royal Infirmary, Edinburgh. Of

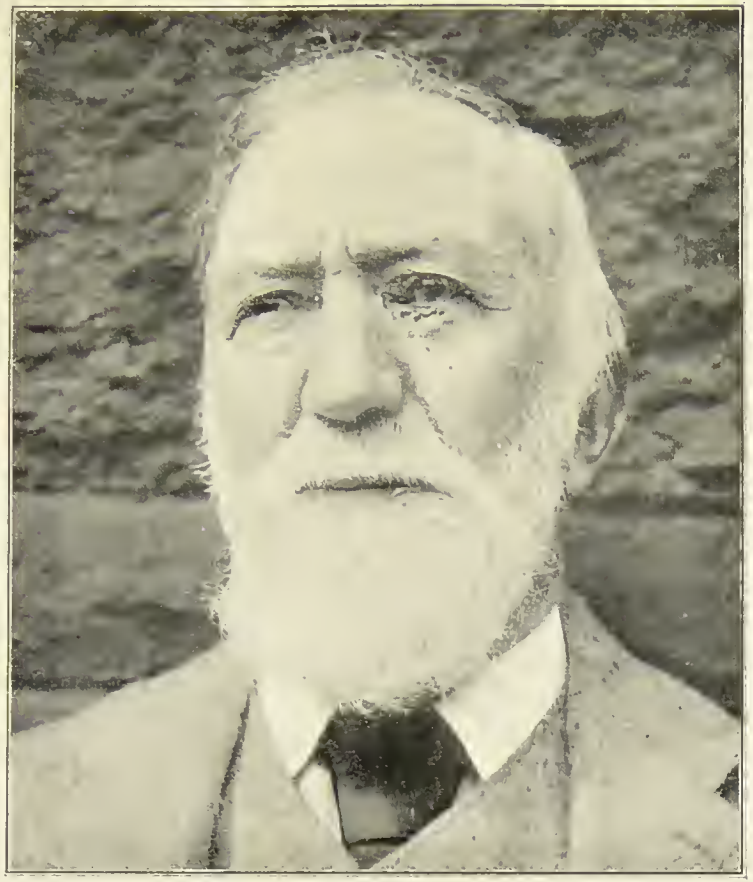


FIG. 14.—RODENT ULCER BEFORE TREATMENT.

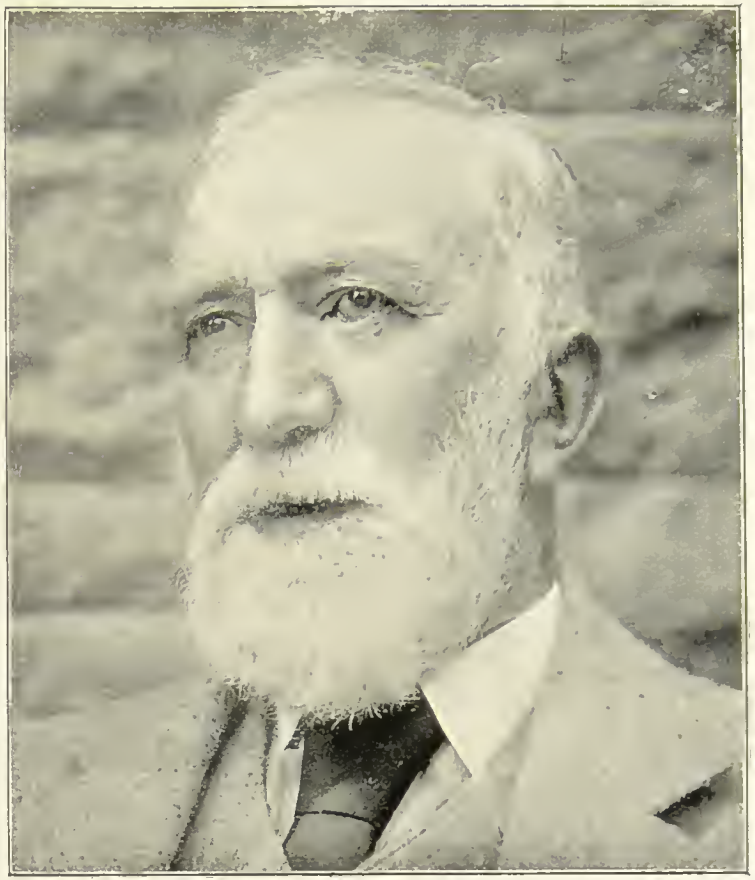


FIG. 15.—RODENT ULCER AFTER TREATMENT.

these six were cured, one is under treatment, three did not return (one of these was greatly improved; this was one of two cases recommended to me by Dr. Fraser, the Superintendent of the Infirmary at Dundee. It was a very bad case of twenty years' duration, affecting the right orbital cavity. Mr. Dowden gave him a bed in October, 1912, and I treated him with radium continuously day and night for five days), and the remaining case was unsuitable for radium treatment. Of the cases that were cured, one affected the upper lip, and was on the point of penetrating it. Three were in the furrow between the nose and the cheek; they had received unavailingly prolonged X-ray applications. One was on the ala nasi—a case of Professor Caird's, in a male of eighty-two (Fig. 16): the rodent measured $\frac{3}{4}$ by $\frac{1}{2}$ inch, and was on the point of penetrating. A single dose of 65 milligramme hours sufficed to cause complete healing, with a beautiful cosmetic result (which greatly pleased Professor Caird) and no contraction (Fig. 17). The disease, however, recurred a little distance off on the tip of the nose. An application of radium was accordingly made to it with a completely successful issue. In another case of Mr. Caird's, a male of sixty-one, the disease began many years ago as a pimple on the right side of the nose. Eight years ago this was removed. On its return, but now affecting the internal canthus, Mr. Caird operated twice, in 1909 and 1912. On the latter occasion, recognizing that he had not been able to remove all the growth, he recommended

him to me for radium treatment. I placed two tubes of radium in the cavity, which was nearly 2 inches deep, and kept them there for thirty hours (300 milligramme hours). No screen was used except a thin tube of aluminium; this was on May 4, 1912. In July the cavity had almost filled up, but for precaution's sake I applied a tube containing 47 milligrammes of pure radium bromide (International Standard) for thirty minutes (23·5 milligramme hours). In December, 1912, he reported himself quite cured. Two of the cases of rodent ulcer were treated by the insufflation of the radio-thorium emanation. One of these was a male, aged forty-six, recommended by Professor Caird. Six years previously Dr. G. Mackay had removed the left eye. The disease had recurred, and was now in the form of a sloughy ulcer about the size of half a crown below the left orbital cavity, and leading to extensive excavations beneath the cheek. As the disease was too extensive and too difficult of access for the amount of solid radium then at my disposal, the idea occurred to me to treat it by blowing into it the radio-thorium emanation, which would be carried into the remotest corners of the excavations, and would coat the walls with a highly radio-active deposit. This was done some twenty times in the course of a few hours, and the immediate effect seemed to be to diminish the fœtor. Unfortunately, the patient did not return for further treatment.

The second case treated by the emanation was a

FIG. 16.—RODENT ULCER BEFORE RADIUM TREATMENT.

FIG. 17.—RODENT ULCER AFTER RADIUM TREATMENT.

male, aged sixty years, recommended by Mr. Wallace. The duration of the disease was fifteen years; he had been treated by X rays, and had had his left eye removed by Mr. Wallace three years before. A later operation had also been performed by Mr. Wallace. At the time the radium treatment was begun there was an ulcer with everted edges occupying the left superior border of the nose, and extending deeply into the orbital cavity. As he was an in-patient, I instructed the nurse to insufflate the cavity with the emanation every half-hour during the day for one minute at a time. After ten days of this treatment it was thought advisable to supplement the emanation by the application of solid radium. After four days of the combined treatment he was sent home. He had had 176 insufflations of the emanation, and 235 milligramme hours of solid radium. A fortnight later he returned very much improved; the nasal ulcer was practically healed. When another fortnight had elapsed, he was re-admitted, and treated again by the combined method for three days. On his reporting himself a month later (January 8, 1913), there was a further improvement. The total dose was 208 insufflations of the emanation, and 675 milligramme hours of solid radium. He has not reported himself since.

Rodents which are situated on the mucous membranes or on the cutaneo-mucous surfaces are not nearly so amenable to radium. For these Dominici recommends ultra-penetrating rays. The radium rays must be filtered through 0·5 to 3 millimetres of lead,

and also through several folds of paper and a piece of india-rubber, in order that Sagnac's rays (p. 28) may be cut off. Only the hard beta and the gamma will get through, and very long exposures of several hours are required. This greatly adds to the difficulty of treatment.

CHAPTER VII

ANGIOMAS

Angiomas can be very successfully treated by radium. The most amenable are the capillary nævi of infants, and the most troublesome are port-wine stains in adults.

The treatment of a capillary nævus in a child is very simple, and the result very satisfactory. Administer a dose of about 5 milligramme hours, as a rule without a shield, and leave it alone for six weeks, when it will probably be found to have completely disappeared. If it has not, a second dose can be given.

Case 16.—A baby, aged six months, recommended by Dr. James Graham. On the right side of the baby's nose was a capillary nævus about the size of a sixpence. This started as a small spot, and has grown rapidly. Ten milligrammes of pure radium bromide were applied without any shield except a mica window for twenty minutes (total 3·3 milligramme hours). Three days later a tiny white speck appeared in the middle of the nævus, and very slowly spread over its whole surface. Now, nine months afterwards, the position of the nævus can scarcely be distinguished

from the surrounding skin (Figs. 18 and 19). Figs. 20 and 21 represent a worse case affecting the cheek.

Nævi of the Scalp.—Owing to the destructive action of radium on the hair follicles, it is open to question whether this agent should be used in the treatment of nævi on the scalp, as a bald spot is apt to be left.

Erectile angiomatous swellings in children yield rapidly to radium treatment; séances of 5 to 10 milligramme hours can be administered either without or with a shield; the latter is usually unnecessary, for the application of the whole radiation will in these cases rarely provoke much skin reaction.

Pigmentary nævi can be removed by the destructive action of radium. The exposure must be regulated by the depth of the affected tissue, but sufficient doses must be given to destroy the pigmented skin and the hairs which are commonly present. After the whole surface has been so attacked, a long time should be allowed to elapse for the inflammation to subside and for the results to become manifest. This may take some months; treatment can then be resumed to the parts which require it. The patient should be warned of the duration of the treatment, and of the disfiguring inflammation which will be set up. The results of the treatment from the æsthetic point of view are excellent.

Case 17 (Figs. 22 and 23).—A boy aged five, recommended, by Dr. P. H. Ferguson, was brought to me in April 1910, on account of a large brownish-black pigmented nævus of the left ocular region. This was

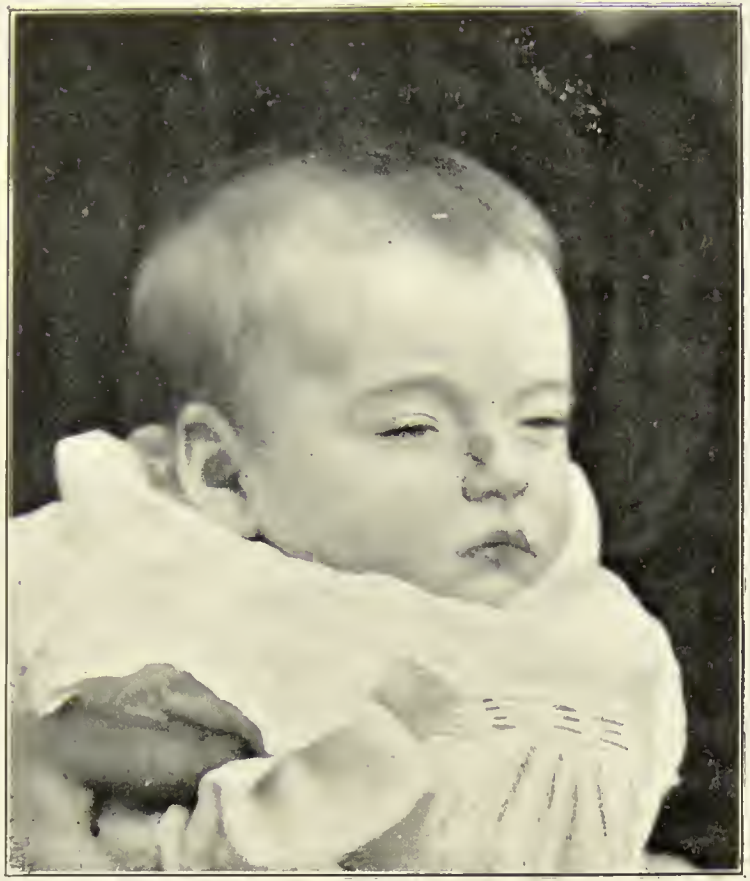


FIG. 18.—CAPILLARY NÆVUS BEFORE TREATMENT.

FIG. 19.—CAPILLARY NÆVUS AFTER TREATMENT.

PLATE V.

FIG. 20.—NÆVUS OF CHEEK BEFORE RADIUM TREATMENT.

FIG. 21.—NÆVUS OF CHEEK AFTER RADIUM TREATMENT.

FIG. 22.—PIGMENTARY NÆVUS BEFORE TREATMENT.

FIG. 23.—PIGMENTARY NÆVUS AFTER PARTIAL TREATMENT.

noticed at birth, but it has since been growing. It now measures about 2 inches in each direction. A photograph was taken on April 19, 1910. Ten milligrammes of pure radium bromide were applied in an aluminium box direct to the patch, and kept on for an hour; the next day they were applied to another spot, and so on every day or two until the whole of the patch had been treated. In one month's time he had had 120 milligramme hours (10 milligrammes for twelve hours). All treatment was now interrupted, and the reaction produced observed. This was excessive, attended by suppuration and scab formation, which did not clear up for about two months, but then a great improvement was remarked. A few spots still require treatment.

Angiomatous tumours in adults, whether infiltrating or elevated above the surface, are also amenable to radium rays, and are to be treated on the general principles already studied; but a reference must be made to the best method of dealing with port-wine stains. There is no difficulty in removing this disfiguring affection by the destructive action of radium rays; the difficulty is, to know when to stop so as not to overdo it. The results of overexposure are white atrophic areas depressed below the level of the surrounding skin, and looking a little like smallpox pits, and telangiectases (more rarely). From a considerable experience of the treatment of this condition, both with strong and weak specimens of radium, I think the most prudent method, considering the importance of

the appearance afterwards, is to apply weak specimens only. Select a particular area and give it a dose of about 1 milligramme hour, and await the result, and remember that weeks must elapse before this stage is reached. In the meantime you can be treating other spots in the same cautious way. The radium plasters would be of service in dealing with extensive areas, for they yield as a rule a weak radiation, and their use would insure an even application.

If your specimen be one of 5 milligrammes of the pure salt in a glass tube, support it upon some cotton-wool or a thin piece of cork at a few millimetres from the surface of the spot you desire to attack; this will have the effect of increasing the area, but of diminishing the intensity of the radiation. Warn the patient of the duration of the treatment, and arrange for a visit once a week or fortnight.

Case 18 (Figs. 24 and 25).—A female patient, aged twenty-four, recommended to me by Professor Alexis Thomson. On the left side of the face there was a very large port-wine stain, roughly divided into three parts. It extended from the roots of the hair above the ear down to the level of the mouth, and it was about 4 inches in breadth; it was almost entirely superficial. Many remedies have been tried unavailingly. A photograph of the face was taken on April 26, 1909, and treatment was then begun. Ten milligrammes of pure radium bromide, protected by a mica shield and a sheet of tissue-paper, were applied for from half an hour to an hour at a time to different areas; no area was

PLATE VII.

FIG. 24.—PORT-WINE STAIN BEFORE TREATMENT.

FIG. 25.—PORT-WINE STAIN AFTER PARTIAL TREATMENT.

PLATE VIII.

FIG. 26.—PORT-WINE STAIN BEFORE TREATMENT.

FIG. 27.—PORT-WINE STAIN AFTER PARTIAL TREATMENT.

exposed a second time until all reaction had passed off. The applications were at first sometimes followed by headaches. When subsequent applications were made to a spot which had been previously treated, a more intense reaction followed. This patient has had a total of fifty-five hours' exposure, or 550 milligramme hours, spread over many months—in fact, over more than a year—but she has been irregular in attending. The result is a great improvement. Over about half the original area the natural colour of the skin has been restored; it is difficult in some places to make out the original extent of the disease. In other places white atrophic spots have appeared, which might have been avoided had weaker specimens only been employed.

In treating port-wine stains, a good maxim is, "Surtout point de zèle." The photographs show the value of radium treatment in this intractable condition.

I will now refer to a case of a similar nature treated by weak preparations only of radium.

Case 19.—A female patient, aged twenty-five, was admitted to the Electrical Department in January, 1910. On the right cheek there was a port-wine stain of a dark purple-red colour; it was congenital in origin, and measured 2 inches in length and $1\frac{1}{4}$ inches in breadth (Figs. 26 and 27). There were also similar stains on the neck and temple. A photograph was taken before treatment was begun. The patient was treated by weak preparations of radium containing either 0·7 or 1 milligramme of the pure salt. She attended twice a week, and had one to two hours' exposure on each

occasion; no shield was used except the glass wall of the containing tube. During the exposures she read a book, and during the whole course of the treatment she has experienced no inconvenience whatever. She has now had six months' treatment and a total of 95 milligramme hours (1 milligramme applied for ninety-five hours). The result, as will be seen from the photographs, is a great improvement. The dark colour has been gradually discharged without the production of any whitish atrophic patches.

Warty Growths.—Warts and corns can be readily removed by radium rays. Apply a 10-milligramme-hour dose to a small wart, and in three weeks' time it will probably have disappeared, sometimes from a sort of absorption, and sometimes by an inflammatory process which causes a shedding of the wart. The inflammatory process may be a little painful—hence it is well to commence by a small dose. Also refrain from treating too many warts at one time on the same hand.

Case 20 (Figs. 28 and 29).—On one occasion I treated four warts on the right hand of a lady, giving each a dose of 10 milligrammes, for one hour, of pure radium bromide—10 milligramme hours—in a space of two days. In about a fortnight she wrote to say that nothing had followed, and that no change had occurred, and that she feared that the treatment had failed. In another week's time she wrote again to complain of the effect of the treatment; the warts were swollen and sore, two had dropped off, leaving a raw surface,

PLATE IX.

FIG. 28.—WART BEFORE TREATMENT.

FIG. 29.—WART AFTER TREATMENT.

FIG. 30.—PAPILLOMA BEFORE TREATMENT.

FIG. 31.—PAPILLOMA AFTER PARTIAL TREATMENT.

and she could not shake hands or write. The irritation passed off in a few days' time, and the warts have not recurred. No shield should be used in treating a wart.

Papillomata yield readily to radium rays. Case 21 (Figs. 30 and 31).—A patient, aged seventy years, recommended by Dr. McEwan, was admitted to the Electrical department of the Royal Infirmary on October 15, 1909. She was suffering from a papillomatous growth on the left cheek. Ten years previously a similar growth had been removed, and there had been no recurrence for some seven months. During the last year the growth had extended rapidly. It now measured 2 inches by $1\frac{1}{2}$ inches, and it projected about half an inch from the surface of the skin. Treatment with radium was begun on October 15, and on November 25 of the same year the patient was discharged, the growth having disappeared. The total exposure was 43·3 milligramme hours.

Leucoplakia, Lupus, Lupus Erythematosus, etc. —The French authorities recommend radium in leucoplakia; I have had experience of four cases so treated.

Case 22.—The first one was a lady of fifty, a patient of Mr. J. Struthers. She had suffered for the last year from this condition, and also from ulcers at the front of the tongue. There were two chief patches of leucoplakia on the dorsum, and an ulcer at either side. For the last three months the patient had been unable to eat without pain, and had been obliged to confine herself to soft food well soaked. After two

applications, of one hour each, of 10 milligrammes of the pure salt, equivalent to 20 milligramme hours, she returned to say that all discomfort in eating had disappeared, and that she had again been able to enjoy hard food. The ulcers healed rapidly, the leucoplakia slowly; every application produced a feeling of relief, and made her tongue feel more natural. She had in all a dose of 127·8 milligramme hours, and she returned three months later to express her gratitude and to show her tongue, which was in almost a normal condition. Mr. Struthers wrote to say how glad and interested he was to see how well the patient was. "The tongue is certainly very much better than when I saw her last. She is not safe yet from the possibility of carcinoma, but there is no sign of it now."

Case 23.—A second case was that of a male, aged forty-nine, recommended by Dr. John Spence. Six weeks before admission to the Electrical Department the patient became aware of a crack on the dorsum of the tongue, an inch from the tip. This did not tend to heal, and the patient saw his doctor, who cauterized the crack, which had now more the appearance of an ulcer, with zinc chloride. This treatment was repeated on six occasions in a month, in addition to the daily use of glycerine and tannic acid. The condition did not improve. Mr. C. W. Cathcart now saw the patient, and expressed the opinion that it was a case of leucoplakia, and suggested an operation. Treatment by radium was commenced with a weak specimen con-

taining 0·7 milligramme of the pure salt, for half an hour to an hour at a time, at first at the Royal Infirmary, and afterwards by Dr. John Spence. Improvement was rapid, and eight exposures sufficed to bring about a complete cure. The total dose was only 5·6 milligramme hours.

Case 24.—The third case was that of a seaman, aged thirty-seven, recommended by Mr. Wade. This patient had on either side of the tongue two very hard, elevated white patches. As the patient refused operation, vigorous treatment with radium was commenced; but the case could not be followed, for as soon as improvement had begun the patient took a ship and disappeared.

Case 25.—The fourth case was that of a male, aged fifty-two, recommended by Professor Alexis Thomson. Specific history. Duration, three years; during the last two he has been receiving radium treatment. On the surface and side of the left half of the tongue there were several hard, whitish patches somewhat raised above the surface. Patient has refused operation, but has had prolonged courses of specific treatment, including salvarsan. Ten milligrammes (International Standard) of radium bromide were enclosed in an aluminium box, and applied twice a week to the patches for an hour at a time. The effect of this was to improve and check the development of the disease, because if it was intermitted as in the holidays the condition rapidly became worse. After this treatment had been followed for two years I recommended more

frequent and stronger applications in the hope that they would produce more lasting benefit; unfortunately, this hope was not realized. The surface of the patches was made brown and sore, but the condition was not ameliorated. Finally, the patient submitted to the removal of the affected portion by operation.

Radium, therefore, did not produce any permanent benefit in this case.

The aluminium container with handle, referred to on p. 30, will be found useful in these cases. It is water-tight, and is easily held by the patient. No screens should be interposed. The dose must depend upon the thickness and duration, etc., of the patch. Case No. 23 was the most satisfactory one, for the radium brought about a very rapid cure, and it seems to me that in suitable cases this treatment certainly deserves a trial. The applications will be followed by an ulceration, which will cicatrize rapidly.

In **lupus** radium does not seem to be especially indicated. I have seen improvement result from its use in localized cases, but not more than could be obtained by other methods. No screens should be used. Its most useful field in lupus is in cases affecting the cavities which are difficult of access for other methods of treatment. Thus, a tube can easily be placed in the nares, and I have seen good results follow such applications.

In the Report of the Radium Institute (*British Medical Journal*, January 25, 1913) it is stated under the heading *Lupus Vulgaris :* " Treatment with Finsen

light is to be preferred to radium in cases of this disease, and, whenever possible, it should always be adopted. If radium be used, however, half strength or full strength applicators should be employed without a screen, and a destructive reaction produced." On the other hand, the Annual Report of the Lupus Institute of Vienna for 1912 (*Lancet*, August 9, 1913) states that "of 2,061 patients, 615 were treated with 11,764 applications of radium, the majority being of long duration. (Each patient received, then, on an average twenty applications.) This radium method of treatment is making good headway as one of the most satisfactory remedies for bringing about permanent recovery from lupus, and several demonstrations proving its efficacy have been given before various medical societies." From this report it would appear that stronger and more prolonged doses of radium are required in lupus.

In **lupus erythematosus** the remedy is of more potency. In a case (No. 26) affecting the scalp in several discrete areas, to which various remedies had unavailingly been applied (including the zinc ion), a dose of 10 milligramme hours (10 milligrammes for one hour) to each patch produced remarkable improvement, practically amounting to a cure; but whether this has continued or not I do not know, as I have not seen the patient for several months. The radium should be applied to the borders and a little beyond the borders of the patch. The radium should be directly applied without screens, and full doses should be administered.

No success will attend too short or too weak applications. An impetiginous crust will form after the application, and not until this has fallen off will the effect of the treatment be observed. Perfectly healthy, soft, fresh skin was revealed in the case I have referred to, to the great gratification of the patient.

Dr. Masotti (" Traitement des Dermatoses par le Radium ") recommends a preliminary scarification. The scarifications should not be so deep as in lupus vulgaris; they should be followed, after the bleeding has been arrested and the part washed, by the applications of radium.

Cheloid.—Wickham and Degrais speak highly of the value of radium in cheloid, and the author can confirm their remarks: " Radium exercises on cheloids a most distinct curative action. The results consist, after a proper length of treatment, in the levelling of elevations, the bleaching of erythematous cheloids, the removal of the pain in the case of painful cheloids, and the restoration of suppleness to the tissues. The most important point in the treatment, and one which the practitioner must never lose sight of, is the necessity of influencing the cheloid to its very base, and of attacking the peripheral roots, which often extend beyond the visible limits. Either the specific or the destructive action of radium can be used. The docility of the tissues of a cheloid, when brought in contact with radium, depends upon its specific action, which causes them to melt away without becoming the seat of the slightest irritation. The cheloids which are

PLATE XI.

FIG. 32.—CHELOID APPEARING ON PORT-WINE STAIN BEFORE RADIUM TREATMENT.

FIG. 33.—SAME CASE OF CHELOID AFTER PARTIAL RADIUM TREATMENT.

PLATE XII.

FIG. 34.—SAME CASE OF CHELOID AFTER MORE RADIUM TREATMENT.

most amenable to radium are those of recent formation and in process of evolution, and those affecting young children " (" Radium-thérapie," p. 174).

Case 27.—A female, aged twenty, recommended by Dr. Keppie Paterson. Admitted for radium treatment on April 3, 1913. On the left side of the face there is a port-wine stain of congenital origin, extending from the lower border of the eye to below the level of the ala nasi. The lower half is crossed by raised hard fibrous bands extending beyond the red area, and of recent formation and steady growth (Fig. 32). The patient has been treated by carbonic snow six times in three months; this failed to benefit her at all; she has also had applications of nitric acid as well as other caustics without benefit. Lately the cheloid made its appearance, and has rapidly increased and extended. The radium treatment consisted in applications for an hour at a time twice a week of 20 milligrammes of radium bromide (International Standard), unscreened except by aluminium, one third of a millimetre thick. At the beginning of August she had received a total of 348 milligramme hours. Great improvement was manifest; the fibrous strands were no longer visible or raised above the surface; they could still be palpated, but with some difficulty; they had diminished greatly in extent. The red coloration over the lower half had also disappeared. Over the upper half weak preparations are being used with benefit. The patient is still under observation (Figs. 33 and 34).

By employing moderate doses the specific action of

radium should be tried for cheloids of the latter class, and, by employing larger doses, the destructive action in old sclerotic cheloids.

In the case (No. 28) of a suppurating tuberculous gland which had been operated on, and in which a discharging sinus had been left, and a cicatricial elevation and ridge, I tried the effect of radium, but, as the result of every dose was to cause the sinus to close, I had to discontinue its employment.

Masotti recommends the use of powerful apparatus and of destructive doses in cheloid and in cicatricial ridges, particularly in the latter. He also suggests the combination of scarification and of radium applications, as it shortens the duration of the treatment. The duration will depend upon the age of the cheloid and of the patient, and the density and breadth of the cheloid. Screens should not be used.

CHAPTER VIII

MALIGNANT GROWTHS AND ASSOCIATED CONDITIONS

The benefit that can be derived from the use of radium in the treatment of malignant growths depends more upon the nature of the growth than upon its size.

Thus, as we have seen (p. 65), rodent ulcer yields readily to the action of the rays. Lymphadenomas and sarcomas are also readily influenced, but not to the same extent as rodents, but the true carcinomata are less amenable. The position of a growth plays an important part in the prognosis. Those that are superficial, localized, and circumscribed, are the most favourably situated, for then they can be attacked on all sides and from the interior; deeply situated growths, as in the thorax or abdomen, are with difficulty affected except by considerable quantities of radium well shielded to protect the skin; they would be best treated by the insertion of a tube of radium by a surgical operation.

Growths affecting the mucous membranes are less amenable than those affecting the skin; thus, if an epithelioma of the lip or cheek should spread or per-

forate to the buccal cavity, it will be more refractory to radium rays. Where there is extensive infiltration and glandular involvement, the prognosis is necessarily more serious. There is not often an opportunity of treating early cases of malignant disease with radium, for in the present state of our knowledge operation, where possible, offers the best chance of success. Dr. Louis Wickham of Paris made the following general remarks regarding the use of radium in cancer at the July Meeting of the British Medical Association, 1910: "The chief interest of radium was in its power of selection. In this rôle it acted as a caustic of special subtlety, seeking out those elements which it wished to destroy. All tissues were not ground for the selective action of radium, but cancer, angioma, cheloid, etc., presented a particularly favourable field." The lecturer summed up his conclusions as follows:

"1. The excellence of result depends on the possession of great experience and a large quantity of radium.

"2. In the great majority of cases surgery should be associated with radium. If the radium therapeutist is in presence of a case of grave cancer, he should first consult the surgeon, so that the patient may not be deprived of the prompt help of surgery. If the surgeon is in the presence of a case difficult to operate in, he should have recourse to radium, to prepare the ground and diminish the virulence, and again after the operation, to consolidate the tissues. The surgeon can also in his turn prepare the ground for radium, and his

help should be utilized for making the perforations, incisions, partial extirpations, etc., which permit the diminution of the thickness of tumours which the rays have to traverse, and to render the application of radium introduced into the wounds more effective. Surgery should be employed to prepare the way for radium in making artificial orifices, or to conduct the tubes of radium to the tumours through the natural orifices. Surgery must discover the operations for permitting the radium apparatus to penetrate into tumours which are inoperable and deep-seated.

"3. The tumours must be deluged with rays; for this, very powerful apparatus is used in opposition, either in cross-fire, or on the exterior surface of the tumour, or by perforations multiplied in the interior of the tumour. If there be any skin, mucous membrane, bloodvessels, or nerves, to protect, there must be placed between the apparatus and the tissues protective screens, whose thickness will vary in proportion to the power of the apparatus and the duration of the application; but on the quick of the tumours the apparatus can be employed with very light filters, to utilize the maximum quantity of rays.

"4. Like surgery, radium does not affect the general state, neither does it prevent recurrences and metastases. (This is opposed to Mr. Gilbert Barling's experiments, p. 63.) It must be clearly understood that the term 'cure' should be but rarely used, and then should only be attributed to the regression of the tumour itself. To say that radium 'cures' patients

suffering from cancer is to risk deceiving the patient and doctor.

"Even in its thus limited rôle radium is a precious weapon. In our struggle against cancer we are so inadequately equipped that any supplementary arm new and well proven, even were it weak—which radium is not—should be regarded as a precious beneficent aid, and taken into serious consideration."

Chevrier, the Paris surgeon (*Arch. d'Élec. Méd.*, July 10, 1910), agrees that radium, which cures without cicatrix, is the treatment of choice in simple cutaneous epitheliomas without invasion of the glands. By this he probably intends rodent ulcers.

The infiltrated cutaneous variety, which affects the glands, presents a more grave state of affairs, and he questions the prudence, in spite of its apparent efficacy, of simple radium-therapy as the only mode of treatment. But in mucous and glandular epitheliomas he is altogether sceptical. The capital objection to radium applied in these cases, in his opinion, is the very large number of living cells, extraordinarily active and proliferating, which it is expected to destroy. (This is just where radium is at its best, *vide* p. 58.) He pleads for the surgical removal of the tumour, and for the use of radium only as an agent to destroy the microscopical residues which always escape the bistoury, and later give rise to relapses. In the operation wound corresponding to the tumour and to the glands extirpated, he would place radiferous tubes for a varying length of time, according to their intensity.

In the case of a cancer of the breast, he would leave two very active radiferous tubes, one in the central part of the wound, and the other at the summit of the axilla. Further, he would give applications from ultra-penetrating apparatus on the supraclavicular and subclavicular regions on the following days. He repeats finally that the employment of radium as the only therapy against a mucous and glandular epitheliomatous tumour must be renounced, and that the alliance of radium with the bistoury—the former to prevent relapses after surgical extirpation—assures for radium a more modest rôle, but one of certain efficacy.

Dr. Robert Knox, Director of the Radium Treatment and of the Electro-Therapeutic Department at the Cancer Hospital, makes (in the *British Medical Journal*, June 7, 1913) the following apposite remarks in the course of a valuable lecture delivered at the Cancer Hospital: "Admitting that in every early case of malignant disease operative measures should come first, there are some conditions when radium should be our second choice:

"1. The patient may refuse operation, and thorough treatment by radium in early cases may lead to a disappearance of the growth.

"2. Or the patient may not be in a suitable condition for operation, and, again, radium may be found useful.

"3. Or it may be that the operation must be so radical that the risk to life is great. Radium should here be given careful consideration as a remedial agent.

"4. Inoperable cases of malignant disease are gener-

ally handed over for radium treatment. Many of these are hopeless from a curative point of view. Here radium will relieve pain, diminish discharge, check hæmorrhage, and frequently heal up ulcers of considerable size.

"Surgical operations may profitably be combined with the use of radium, and partial operations are a great help, as it is quite rational to remove as much of the tumour as is possible in order to facilitate the use of radium. A large fungating necrotic tumour of the breast is not likely to yield to radium treatment alone, but if the surgeon removes as much of the growth as possible, then radium may be employed on the portions of the tumour left. Secondary deposits in the glands may be vigorously treated by radium, and if a diminution in size is brought about, these may be removed at a subsequent operation. Life may be rendered more tolerable and undoubtedly prolonged by such measures."

Sarcomata.—In the author's experience, sarcomata yield more readily and completely to radium treatment than carcinomata.

Case 29.—The following notes refer to a case of recurrent fibro sarcoma of the back which was treated by me in the Electrical Department of the Royal Infirmary, Edinburgh, by the cross-fire method. This case is retained in the new edition because it illustrates the general method of treatment, although stronger doses would now be given.

A female, aged fifty-six years, recommended by Dr. D. Huskie, of Moffat, and Mr. C. Cathcart, was

PLATE XIII.

FIG. 35.—SARCOMA, FOURTH RECURRENCE, BEFORE RADIUM TREATMENT.

admitted to the Electrical Department on January 10, 1910. She was suffering from a fibro-sarcoma of the back (Fig. 35). About five years ago Dr. Huskie removed what appeared to be a sebaceous cyst from her back. This was, unfortunately, owing to an accident, not examined microscopically. A year later Mr. Cathcart removed a recurrent growth, which proved to be a sarcoma, and again last year he removed a second recurrence. On admission there was a swelling on the back, above the site of operation, about the size of a large plum. During the next fortnight she had seven applications of the X rays, from which she received some benefit, and she then returned home. On May 27, 1910, she returned because the growth had increased greatly in size. The growth was now photographed, and a cast of it was taken by Mr. Cathcart. It was now about the size of a large teacup or bowl, and was raised $2\frac{1}{2}$ inches above the surface; it measured 6 inches in length and 6 inches in breadth.

A silver tube 0·5 millimetre thick, containing 5 milligrammes of pure radium bromide, and having a silver wire attached to it, was inserted by means of a trocar into the growth. After remaining for seventy-two hours in one position, it was moved along the tract a little by means of the wire; it was left in this position for forty-eight hours, and then taken out and reintroduced into another part of the growth, where it rested for eighty-six hours; total internal application, 5 milligrammes for 206 hours, or 1,030 milligramme hours. Meantime I applied daily externally a speci-

men of 10 milligrammes of the pure bromide, shielded by 0·5 millimetre of silver to save the skin. Care was taken not to reapply this twice to the same position. The neoplasm was now between two fires, with the result that it ceased to increase and that the stinging pain disappeared. After fifty hours' external application—500 milligramme hours—all treatment was suspended. Seventeen days later, as no excessive reaction had been produced, 5 milligrammes of the pure bromide were again introduced into another part of the growth, but this time enclosed in an aluminium tube only. It remained in for 240 hours, but its position was twice altered. The dose was 1,200 milligramme hours, but the effect was much greater because the silver shield had been omitted. On July 24 the tube was extracted, by making an incision, by Mr. Cathcart, as the silver wire had broken. The patient had now had in all 500 milligramme hours externally and 2,230 milligramme hours internally. The tumour was now much reduced in size, and also firmer. The skin was reddened in places with a few slight scales, but had escaped all serious irritation. The patient felt better, and looked better and stouter. She was now sent home for a rest.

On September 23, eight weeks and three days later, she returned; she stated that she had been a great deal better during the holidays, and that her shoulder had felt easier until a week ago, when it began to feel less comfortable. The growth, on comparing it with the cast taken on May 27, was found to have the

same over-all dimensions—6 inches by 6 inches—but was slightly more prominent and nodular in two places (these places were the farthest away from the points where the radium had been buried), and slightly flatter and more shrunken in regions nearer the graves. Treatment will now be resumed by the insertion of tubes of radium and by the external application of radium. Among the chief points of interest in this case are: (1) The remarkable effect of the treatment in delaying the growth of the tumour; in the previous six months the tumour (fourth recurrence) had grown to its present dimensions; in the succeeding four months, two of radium treatment and two of rest, it had practically ceased to increase. (2) The innocuous character of the treatment; the radium, screened by 0·5 millimetre of silver, lay first for eight days, and then, screened by 0·3 millimetre of aluminium, lay for ten days, in the tumour—total, eighteen days fourteen hours—and yet it produced no sensible rise of temperature or visible necrosis. In tumours other than fibrosarcomas which I have treated similarly by the introduction of a tube of radium, some necrosis may follow the applications.

A Recurrent Lymphosarcoma.*—Case 30.—A male, aged sixty-five, was recommended to me by Professor Alexis Thomson for radium treatment in June, 1911. He was suffering from a recurrent small-celled lymphosarcoma which was inoperable. The first operation

* Communicated to the Edinburgh Medico-Chirurgical Society on November 6, 1912.

had been performed on August 21, 1909. The tumour was then situated in the axilla, and both pectorals were divided to permit of its removal along with a number of satellite glands. On microscopical examination the growth was found to consist of a small-celled lymphosarcoma (Figs. 36 and 37). About a year and a half after the operation there was a recurrence; this took the form of a swelling somewhat deeply placed below the left clavicle, and of enlarged glands in the neck, forming a mass of about the size of a small orange. There were no symptoms beyond some stiffness and tightness in moving the left arm.

Radium treatment was begun on June 13, 1911. The tumour was attacked both from the outside and from the inside, and the glands from the outside. A glass tube in an aluminium case containing 20 milligrammes of radium bromide was inserted by Professor Thomson into the mass below the clavicle. The tube was attached to a silk thread so as to enable it to be withdrawn when desired. At the same time external treatment to the glands above and to the swelling below was commenced. A capsule containing 40 milligrammes of the salt was applied daily for four hours to the glands above, and for four hours to the swelling below. The capsule was made of aluminium $\frac{1}{3}$ millimetre thick, and a screen of silver $\frac{1}{2}$ millimetre thick was interposed to protect the skin from the alpha and soft beta rays. The applications were also always made to different areas, no one area getting more than a single dose. As a result of this precaution the skin

PLATE XIV.

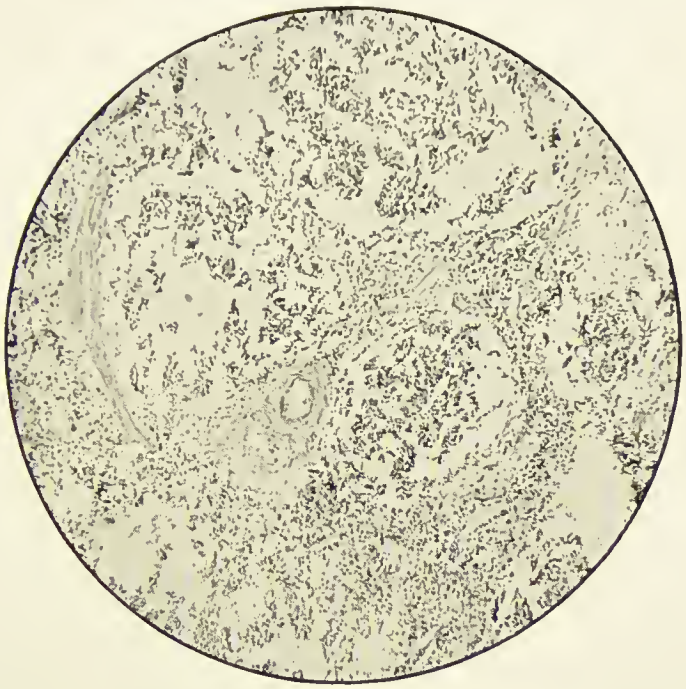


FIG. 36.—LYMPHOSARCOMA: HIGH POWER.

FIG. 37.—LYMPHOSARCOMA: LOW POWER.

never showed more than a moderate reaction. After remaining *in situ* for a week the internal tube was moved a little by its thread so as to expose a fresh surrounding to its influence. After a lapse of thirteen days the internal tube was removed altogether. Professor Thomson now observed that the tumour had ceased to grow. The external treatment was continued a few days longer. The total internal dose amounted to 6,240 milligramme hours, the external dose to 8,680 milligramme hours. On examination a fortnight later considerable improvement was observed; both the enlargements had diminished in size, particularly the lower one.

There was, however, a glandular mass somewhat deeply placed above the clavicle, which owing to its depth could not easily be reached by the external application of radium, and accordingly it was resolved to insert a tube of radium into it. A week later Professor Thomson attempted to do this, but found it impossible without exposing the glands by an open operation; he therefore gave a general anæsthetic and resected the greater part of the clavicle, and as he found, on exposing the glands, that he could remove the main mass, he proceeded to do so. Thereafter a tube of radium was placed in the cavity and left there for one week. The dose was one of 3,360 milligramme hours.

Three months later, on October 22, 1911, the patient was examined by Professor Thomson, who could find no trace of the disease. Two years have now elapsed,

and the patient has remained quite well and been able to engage in his ordinary avocations.

Professor Alexis Thomson made the following remarks regarding this case: "This was both clinically and microscopically a small-celled sarcoma; it was inoperable, and in my opinion death would have been inevitable in two or three months had it not been for the radium treatment." *

The following case illustrates the use of radium in the interior of the mouth:

Case 31.—A male, aged fifty years, recommended by Professor Alexis Thomson, was admitted to the Electrical Department of the Royal Infirmary on August 13, 1909, suffering from a neoplasm, probably of a transition type, involving portions of the hard and soft palates. He had been ill for about a year, and a full course of iodides and of mercury had been taken without benefit. Professor Thomson had on two occasions excised portions of the growth for microscopic examination, without clearing up the diagnosis. Had the diagnosis been that it was definitely cancerous, he would have attempted to remove it, but failing such a diagnosis the operation seemed too serious a one to subject the patient to. This patient was at first treated with the X rays by a tube, whose prolongation could be inserted in the mouth. After twenty applications had failed to produce any benefit, radium was tried. Ten milligrammes of pure radium bromide were placed in the aluminium appli-

* The patient has just (October, 1913) been re-examined by Professor Alexis Thomson, who found no evidence of disease.

cator described on p. 21, and by means of the rod were maintained by the patient against the growth for about an hour at a time. Improvement began at once, and after ten hours' exposure—total, 100 milligramme hours—I sent him to be re-examined by Professor Thomson. The latter wrote on November 25, 1909: "Decidedly improved, especially on the left side, where healing appears to have started."

The patient continued to attend for radium treatment once a week, and sometimes less often, until the August holidays, when for eight weeks all applications were interrupted. During this interval the growth resumed activity, and when an exploratory incision showed that it had taken on a definitely epitheliomatous character, Professor Thomson removed it by operation. There can be little doubt that the radium treatment kept this growth in check.

I have used radium with temporary benefit in certain epitheliomas of the face, lips, and glands of the neck, but where perforation into the mouth has occurred the remedy has failed. In all cases where it has been possible to insert and leave in a tube of radium, the beneficial effect has been greater. This would lead one to conclude that very much longer exposures and stronger doses are indicated in malignant disease. When a tube of radium is inserted in a tumour, we may liken it to a little sun, which is all the time and in every direction projecting its beneficent rays, all of which must pass through the growth; but the rays of radium are superior to the light rays of the sun in one respect, and that is in their power of penetration.

They are not stopped by the first layer of cells, for the harder rays traverse the whole body. If radium can be applied externally as well, so much the better, for the neoplastic cells will now be subjected to a cross-fire. In applying radium externally, it must be remembered that we are only utilizing a very small portion of its radiation, the greater part escaping from the back and other sides of the specimen; but when it is buried internally, then none of its radiation can escape without traversing the neoplasm. Where the external dimensions of the growth are large, it would be well to apply the X rays as well as radium. Where the skin is intact, both forms of radiation must be filtered, the X rays through 0·5 millimetre of aluminium, and the radium through 0·1 to 0·5 millimetre of silver.

For the refractory epitheliomas of the cutaneo-mucous or mucous surfaces Dominici recommends the ultra-penetrating rays (*vide* p. 77), obtained by screening the radium through lead of half to several millimetres in thickness, several sheets of paper, and an envelope of india-rubber. Unshielded radium, which gives remarkable results in cutaneous epitheliomas, is dangerous for cancers which encroach on the buccal mucous membrane, as they may stimulate rather than arrest their development. Gaucher has pointed out that the same rule holds for certain caustics. In Dominici's opinion, the use of the ultra-penetrating rays, and the prolonging of their action on the diseased tissues, is especially suitable for epitheliomas of the

mucous membrane. This opinion, with which Professor Gaucher is in accord, is confirmed by the rapidity with which tumours of the labial mucous membrane disappear under the influence of the ultra-penetrating rays, and by the tolerance of the tissues of the lip towards these rays. These facts have led Dominici to try the same method of treatment in cancer of the tongue. The results so far obtained at the St. Louis Hospital seem to show that malignant neoplasms of the tongue are also amenable to radium-therapy ("Diseases of the Skin," E. Gaucher, p. 295).

Dominici is of opinion that the least penetrating rays, the alpha and the soft beta, cause most alteration in the healthy tissues, and that the most penetrating rays, the gamma and the hard beta—that is, the least alterative—have an extremely powerful therapeutic action.

Deep-seated cancers can only be satisfactorily attacked by the introduction of tubes of radium; for this purpose the natural passages, or sinus, or incisions made by a surgeon, will serve. The glass tube containing the radium salt must be enclosed either in an aluminium or silver or platinum or gold tube, the metallic thickness being from 0·2 to 0·5 millimetre. To this a soft silver wire should be attached, to enable the tube to be withdrawn. Dominici and Cheron cite a case of lymphadenoma of the parotid region, the region being completely hypertrophied, and the tumour encroaching upon the temporal region above and the maxillary region in front. It was judged to be inoperable. An incision with the bistoury was made in the

centre of the neoplasm, and a gold tube containing 5 milligrammes of radium bromide, of 4,300 activity, was introduced (unless there is a misprint here, the strength is very small, and equal to about 0·017 milligramme). The apparatus was maintained in position for five days, when there was evident improvement, and at the end of seven weeks this improvement had become a definite cure. This patient was shown before the section of Radiology at the British Medical Association meeting in London, July, 1910.

Another case shown by these gentlemen to the Radiology section was that of a deep sarcoma of the neck. In July, 1907, two years before treatment was begun, the tumour appeared as a small nodule under the right lower jaw, increasing very rapidly in size in the previous three months. At the time of examination it was purplish in colour, with blood and serum oozing from several orifices. Histological examination showed its structure to be that of a pure embryonic sarcoma. In July, 1909, three tubes, each containing 0·5 milligramme of pure sulphate of radium, with a silver sheath 0·5 millimetre thick, were introduced for forty-eight hours (72 milligramme hours). Seven weeks later a deep, indurated, flat mass represented the tumour, which, however, recurred, or, rather, again showed active growth, in November, 1909, when the treatment was repeated with apparently definite success. A small nodule now existed near the cicatrix.

Carcinoma of the Alimentary Canal.—Carcinoma of the œsophagus can be treated by enclosing a tube of

radium in a special form of bougie, which is then passed down and maintained at the seat of the disease for as long as may be possible. Strong preparations are therefore to be preferred in order to shorten the exposures. Several cases have been recorded in which the symptoms due to stricture were relieved and the condition ameliorated.

Carcinoma of the stomach can only be really ameliorated or benefited by the introduction of tubes of radium after laparotomy. Milder degrees of benefit have been claimed from the outward application of strong preparations screened by 1 to 4 millimetres of lead. These must be maintained for many hours in position.

The same system can be employed for disease of other portions of the bowel except the rectum.

Carcinoma of the rectum appears to be more amenable to radium than when situated in any other portion of the alimentary canal. The radium contained in the applicator (Fig. 8) is introduced, through an operating sigmoidoscope if desired, and maintained by means of the aluminium or silver rod in contact with the diseased part. If it be ulcerating, avoid any screen except a sheet of rubber tied round the applicator; otherwise use a sheet of silver half a millimetre in thickness. The dose must depend upon the extent, etc., of the disease. Care must be taken to protect, by means of a suitable screen, any healthy mucous membrane. For an annular growth a rubber tube containing radium is more suitable. The following case is taken from the Annual Report of the Radium Institute

(*British Medical Journal*, January 25, 1913): "In a patient, M., aged sixty-one, there was a six months' history of alternating diarrhœa and constipation. Immediately before coming to the Radium Institute he had been examined by a well-known surgeon, who declared him to be suffering from an inoperable carcinoma of the rectum. On examination, a growth could be felt 5 centimetres above the anus; it was firmly fixed, annular, and ulcerated; the lumen of the growth admitted the tip of the little finger. Fifty milligrammes of radium in a tube, covered by a screen of 2 millimetres of lead, were applied in the lumen of the growth for six hours a day for ten days (3,000 milligramme hours). A month later considerable improvement was noted. The growth wasmuch smaller, and covered with smooth intact mucous membrane. Above the stricture could be felt one or two nodules. Treatment as before was repeated for five days. Five months later no infiltrating growth could be felt, and only what was apparently an easily dilatable stricture remained."

In less successful cases there will be some amelioration, such as relief from pain and hæmorrhage, complete or partial healing of an ulcerated surface, improvement in general condition, and prolongation of life. Sometimes a case that was inoperable is rendered operable.

Disease of the prostate might be attacked by heavily screened apparatus through the rectum or *per urethram*, the radium tube in the latter case being screened on the side of the healthy tissues. I think this should be

given a trial in simple hypertrophy; some necrosis and diminution of the obstructing lobe could certainly be produced.

Dr. Hugo Schüller (Vienna), in a paper read at the Seventeenth International Congress of Medicine, referred to ten such cases with more than three years' complete retention which were treated by radium; of these, two were completely cured, four ameliorated, and four remained refractory.

Cancers affecting the buccal cavity have already been referred to.

Carcinoma of the Breast.—Primary growths of small size, recurrent nodules, and secondary superficial tumours, rapidly melt away when properly attacked by radium. Glands may be more refractory, but can be kept in check and brought into a quiescent condition, in which they can be removed by operation. Whenever possible, tubes should be inserted into the growths.

Case 32.—A female, aged fifty-four, recommended to the Radium Department of the Edinburgh Royal Infirmary by Mr. Alexander Miles. History: In September, 1911, the patient had been admitted to the Chalmers Hospital complaining of a hard, painful lump in the left axilla. Mr. Stiles removed the mass and the breast; both were found to be the seat of a medullary carcinoma. The patient was readmitted to Chalmers Hospital on May 28, 1912, with a rapidly growing recurrence in the scar; this was excised by Mr. Stiles on May 31, 1912. Patient returned at the beginning of 1913 with a secondary growth attached to the sternum.

The patient was recommended to the Royal Infirmary and admitted by Mr. Miles.

Projecting from the sternum was a hemispherical growth in area about the size of a teacup saucer, and raised above the surface of the skin about 1 inch. The skin over it was erythematous. The patient complained of spasms of severe lancinating pain. Treatment: Two tubes of radium bromide, each containing 5 milligrammes (International Standard), were introduced by Mr. Miles into the growth, screened only by glass and aluminium, and were kept in for seven and for twelve days respectively, being moved occasionally so as to expose a fresh area to the radiations. At the same time applications of 25 milligrammes (International Standard) screened by silver were made externally. The total internal dose was 2,400 milligramme hours. Total external dose was 800 milligramme hours. Under this treatment the tumour rapidly flattened down, and in eight weeks' time had completely disappeared. Some pus was discharged from the tracks of the tubes, and a good deal of reaction was manifest on the skin. The lancinating pain disappeared shortly after the applications. During the following six months two recurrences occurred, both of which, being taken early, quickly yielded to outward applications of radium. The clavicular glands on the affected side next became greatly enlarged with swelling and stiffness of the arm. For a time outward applications were made with benefit to the glands, and afterwards a tube of radium, screened only by glass and

aluminium, was inserted by Mr. Carmichael into the most prominent one. This was kept in for twelve days, the dose being 1,440 milligramme hours. This had an excellent effect, for in two months' time the affected glands had so shrunk as to be scarcely palpable. Scarcely any pus was discharged from the sinus left after the removal of the radium tube.

Recurrent Epithelioma of the Ala Nasi.—Case 33. —A female, aged forty-nine, recommended by Mr. Wallace. Patient had suffered for many years from malignant ulceration of the right ala nasi, which had been operated on three times with a view to excision, and which had been treated unavailingly for several years by X rays and weak radium preparations.

Condition on admission on June 25, 1912: There is an ulcerating crack on the external surface of the right ala nasi. A dose of 95 milligramme hours (International Standard) of radium bromide was administered by a single application. The scab did not come away until the middle of September, when the ulcer was found to be completely healed over. On January 28, 1913, the scar was still in a perfectly sound condition, but a small ulcer had appeared just within the nostril on the septum nasi. This was given a single dose of 40 milligramme hours. It disappeared, and has not recurred since. I quote this case because it illustrates the importance of the dosage. A single sufficient dose caused the disappearance of a disease which had resisted both the knife and prolonged insufficient doses of radium.

The following is an example of a type of case seen too frequently by the radium expert:

Case 34.—A male, aged seventy-two, recommended by Dr. Elder. Malignant disease of the fauces and pharynx. Duration, eighteen months; difficulty in speaking and swallowing. An irregular swelling can be observed involving the soft palate and posterior pharyngeal wall, and causing great deformity. Left cervical glands enlarged. Both Professors Caird and Alexis Thomson considered the case quite inoperable. With a hope of relieving his symptoms, radium treatment was commenced. On September 19, 1912, a capsule containing 40 milligrammes of radium bromide was attached to an aluminium rod, and held by the patient against the affected part for one hour two or three times a week; only an aluminium screen was used. By November 28, 1912, the patient had received a dose of 388 milligramme hours. The applications appeared to relieve his pressing symptoms, but he gradually sank and died on December 14, 1912.

Case 35.—This illustrates the use of radium in prophylaxis. A male, aged thirty-five, recommended by Professor Alexis Thomson. A round-celled sarcoma in the groin. Duration, twelve months; admitted to Royal Infirmary, Edinburgh, on January 11, 1913, complaining of a lump the size of a fist and a half in the groin, also of increasing weakness; the left leg was œdematous. On January 17, 1913, Professor Thomson removed the growth, which proved to be a round-celled sarcoma

On January 30, 1913, a tube containing 10 milligrammes (International Standard) of radium bromide, screened only by glass and aluminium, was inserted into the wound and kept there for twenty-four hours; the dose was 240 milligramme hours. This did not succeed, for in five months' time the patient returned with a rapidly growing recurrence. The author did not expect success, for the dose, owing to the demand for radium by other patients, was much too small; also the application was only made to one small region, whereas the whole of the area from which the growth had been removed should have been treated.

CHAPTER IX

DISEASES OF THE NERVOUS SYSTEM—TUBERCULAR GLANDS—PRURITUS—LEUKÆMIA—GRAVES'S DISEASE—EYE DISEASES—UTERINE CANCER—RHEUMATIC CONDITIONS—COMPARISON BETWEEN X RAYS AND RADIUM RAYS

Diseases of the Nervous System.—Radium has been used for its analgesic action in neuralgia, sciatica, and the lightning pains of locomotor ataxy, and also for certain affections of the spinal cord associated with cellular overgrowth. In the *Progrès Médical* of December 18, 1909, Mme. Fabre and Dr. Paul Touchard, of the Salpêtrière Hospital, report a series of five cases of syringomyelia treated by exposure to radium, with surprising effect.

A piece of flat metal was employed, 6 centimetres square, containing 1·5 centigrammes of pure radium bromide, and a nickel screen 0·33 millimetre thick, sufficient to allow only hard beta and gamma rays to get through. The applications were made daily to the vertebral column, at various levels, alternately to the right and to the left of the spinous processes. The duration of the exposure was at first restricted to ten minutes, but evidence of the innocuousness of the

applications led to their being extended to as long as an hour and a half (each dose would be one of 22·5 milligramme hours). The record is certainly an encouraging one. All five cases improved, three of them to a remarkable degree. All showed increased mobility of the limbs, with diminution of stiffness. One patient's hands had been quite helpless, in a *main en griffe* position, but after radium treatment she was able to flex, extend, and separate the fingers. A second was able to resume his work as a draughtsman after six months' disuse of pencil and compasses. Another remarkable fact was the disappearance, in one case, of the trophic disturbances characteristic of Morvan's disease. The effect on the muscular atrophy was less obvious. Improvement set in very rapidly. From the theoretical standpoint, there is reason to suppose that the action of radium on the syringomyelic cord is analogous to its accepted action on neoplastic tissue. By some mechanism unknown to us, the rays check the proliferating tendency of the cellular elements of new growths, and, on this analogy, it is perhaps only in developing cases of syringomyelia that they are likely to be of service (*Lancet*, January 22, 1910). It has been shown by Beaujard, L'Hermitte, Raymond, and others, that the X rays have a favourable influence on syringomyelia, and it is therefore to be expected that the gamma rays of radium would have a somewhat analogous effect, and more potent, in consequence of the ease with which they can penetrate the bodies of the vertebræ.

Tubercular Glands, Pruritus, X-ray Dermatitis. —As X rays are of acknowledged service in enlarged glands, so are radium rays. I will refer only to some remarks made by Sir Malcolm Morris in the discussion on Wickham's paper on July 20, 1909, and reported in the *British Medical Journal* of August 21, 1909. "Recently he had a case in which the tuberculous glands had been removed on three different occasions, and in order to avoid another surgical investigation, which seemed likely to be equally unavailing, he thought he would try the effect of radium. There were three tuberculous glands. There could be no question as to the accuracy of the diagnosis, for there were the previous operations to go upon and the microscopical proof. He used a filter of lead 2 millimetres in thickness, and gave long exposures, two hours a day for six days, on one gland. At the end of three weeks there was not a trace of the gland left; moreover, the skin was untouched, and there was no sign of a burn. The other glands were treated in the same way, with the same result."

Drs. Wickham and Degrais, Deane Butcher, and others, have reported good results in rebellious pruriginous conditions and in simple pruritus. Sir J. Mackenzie Davidson treated some patches of X-ray dermatitis on his own hands with a 29-milligramme tube of radium for ten minutes, with success. After the reaction had subsided the part was soft and pliable, and not cicatricial, as it would have been under the cautery. He had also obtained remarkable improve-

ment by treating in the same way the extensive lesions on the hands of an X-ray operator.

Dr. Deane Butcher has found that the application of radium has a soothing effect upon X-ray burns, something like that of cocaine. We know also, on his excellent authority, that radium is unapproachable in the treatment of pruritus.

Case 36.—A gentleman, aged forty-three, consulted me for intractable pruritus ani of long standing for which he had unavailingly tried many remedies. No obvious change was to be observed in the condition of the anal orifice, but the itching was chiefly referred to the posterior margin. In June, 1912, I gave an unshielded—except for $\frac{1}{3}$ millimetre aluminium—dose of 5 milligramme hours; a week and a fortnight later he regretted to have to inform me that no benefit had resulted, but three weeks from the date of the application the pruritus disappeared, and has not returned, although more than a year has now elapsed.

It is interesting to note (1) how small a dose was sufficient to cause the complete and permanent disappearance of the trouble, and (2) the time required for the beneficial effect to appear.

Hypertrichosis.—As the X rays, so can radium be used for the treatment of this condition, and each method has its own advantages and disadvantages. The X rays can be applied so as to effect at one time a larger area, but the dosage is somewhat uncertain, and they are more likely to be followed by unpleasant after-effects such as telangiectases. The dose of radium

can be quite accurately measured, and epilation will certainly follow a proper dose, but the effect will be almost limited to the area of the radium container, and it will thus be difficult to produce a uniform epilation over a large area without the use of a varnished applicator (*toile radifere*), cut so as to cover the whole area (p. 21). Unpleasant after-effects are rare after the use of radium.

Case 37.—A female, aged twenty-five, recommended by Dr. Fleming, attended for a week during September, 1912, for the treatment of this condition. The patient had a thick, hairy growth round the lower border of the chin. After the patient had been made aware of the difficulties of the method of treatment, applications screened only by mica of 5 milligramme hours were made to successive areas. These proved to be insufficient to produce epilation. The patient is to return, when stronger doses will be applied.

Strictly limited clumps of hair are the most suitable for radium epilation.

Eczema, Psoriasis, Lichenification.—Good results have been reported by Continental authorities and by the Radium Institute in chronic localized eczema, with lichenification and psoriasis. Short applications of unscreened applicators (a few minutes only) should be tried, and repeated if necessary. Patches of eczema may be permanently cured, but psoriasis is apt to recur. Wickham and Degrais ("Le Radium," p. 85) say: "We have treated 200 cases of chronic intractable eczema with lichenification, and the action of radium

has almost always been particularly favourable in cases affecting the face, arms, hands, ears, lips, and the legs."

Leukæmia, Graves's Disease.—Encouraged by the success with which the X rays have been used in the treatment of these conditions, various authorities have tried radium and thorium. The latter has been used chiefly in the form of thorium X, administered either by the mouth or injected intravenously or subcutaneously (W. Falta, *British Medical Journal*, March 29, 1913; Plesch, *Lancet*, May 25, 1912). Experiments on animals showed that with large doses the leucocytes rapidly diminish in number, and may altogether disappear from the blood. Falta quotes four cases of leukæmia in which favourable results followed the subcutaneous injection of thorium X. Plesch quotes two, but he recommends the intravenous injection as the most efficacious; subcutaneous injection should, he says, be avoided, because necrotic ulcers might develop later. More recently Renon, Degrais, and Desbouis reported five cases of myeloid leukæmia to the Medical Society of the Paris Hospitals, and showed two of the patients, in whom remarkable benefit had been derived from the use of radium (*Lancet*, August 9, 1913). Two of the patients had been treated by X rays without benefit. One case was that of a female, aged twenty-seven, thin and pale; her lips and conjunctivæ were completely white; her abdomen was as enlarged as that of a woman at term. An enormous tumour filled the abdomen with a well-marked notch in its right border. Blood examination showed 3,300,000

reds and 260,000 whites per cubic millimetre. There were 20 per cent. of myelocytes present. On May 18, 1913, 30 centigrammes of radium sulphate, spread over an area of 600 square centimetres, and filtered through 2 millimetres of lead, were applied over the spleen. On June 7 the white corpuscles had fallen to 56,000. A second application of radium was made, and on June 14 the whites had fallen to 19,000, the myelocytes had disappeared, and the spleen was a little smaller. A third application was made on June 22. On July 1 the spleen did not extend beyond the middle line or below the level of the navel. On July 11 the reds numbered 3,700,000, the whites 7,000, and the spleen was still diminishing. This case and the other ones showed that radium has a rapid and powerful effect in myeloid leukæmia when applied to the spleen for twenty-four hours in such strengths (a dose of 7,200 milligramme hours, if the radium was pure and measured on the International Standard). After four to six applications the patient is apparently cured, but after an interval of some months the disease reappears, and a renewal of the radium treatment produces less effect. In the end radium loses all action, and the patient dies after a variable interval. Radium and the X rays appear, therefore, to have a similar therapeutic action, though different physical factors may be involved.

Graves's Disease.—Many favourable reports as to the action of the X rays in this condition have been published. The method has, in fact, become orthodox. Dr. George R. Murray, in his address on Medicine to

the British Medical Association at Brighton (*British Medical Journal*, July 26, 1913) referred to the use of X rays as follows: "The application of suitable doses of X rays to the enlarged thyroid gland has in some of my cases proved to be of great value. The gland gradually diminishes in size, and the other symptoms subside. Atrophic changes in the secretory epithelium and both interstitial and extracapsular fibrosis appear to be induced by the action of the rays. These adhesions between the capsule and the surrounding structures are, however, a disadvantage should a subsequent thyroidectomy be required. In two of my cases in which X-ray treatment was not successful, one lobe of the gland was excised. Microscopical examination showed no fresh change in one, but a distinct increase in the interalveolar connective tissue of the other. These changes are slow in development, so that the full effect of the treatment is not obtained until some months have elapsed. In favourable cases some fifteen to twenty weekly doses of the rays have been sufficient to bring about great improvement or practical recovery, but in others only slight improvement has followed a similar course of treatment. It is worth while to persevere with X-ray treatment for as long as a year if slow but satisfactory progress is being made. We have, however, still much to learn as to the most appropriate dosage and mode of application of this valuable method of treatment." In the author's opinion, which is based not only theoretically upon the similarity of physical radiations, but also

practically upon an experience of four cases, these laudatory remarks as to the action of X rays could quite as justly be applied to the action of radium. But, in addition, radium has two distinct advantages over the X rays: (1) A perfectly definite dose of it can be given and repeated as often as may be desired; (2) the radium can be applied without noise or excitement while the patient is at rest in bed. That this is an important advantage in the treatment of persons suffering from Graves's disease every physician will allow. It was for the latter reason that the author was led to replace the X rays by radium.

Case 38.—A lady, aged sixty-nine, the wife of a physician, had suffered from Graves's disease for two years. Her chief symptoms were tachycardia (the pulse sometimes running up to above 170), nervousness, weakness, exophthalmos, and breathlessness. The thyroid was scarcely enlarged.

In December, 1912, the author was consulted as to the application of the X rays. Only one application was, however, given, for the excitement and fatigue of having to come to the author's house for the application, combined with the noise and spluttering of the X-ray apparatus, appeared likely in the patient's nervous condition to do more harm than good. It then occurred to the author to suggest the employment of radium instead of the X rays. He was unaware of any previous use of radium for this condition, but it seemed reasonable to suppose that, owing to its action in diminishing vascularity (as in nævi) by the

obliteration of small bloodvessels and by the induction of fibrosis, some benefit would accrue.

After consultation with the patient's medical adviser and with her husband, applications of radium were made over the thyroid on each side of the neck. To begin with, an intensive form of treatment was adopted, several applications of 45 milligramme hours screened by $\frac{1}{3}$ millimetre of silver being given in the first ten days; afterwards the applications were given at greater intervals; altogether the patient received in the course of two or three months a dose of 350 milligramme hours. Improvement began very quickly, and has been maintained; the patient's doctor and her husband both agree as to the benefit she has received: "The exophthalmos is less; the tachycardia is less frequent and marked; the pulse, which used to go to above 170, now keeps at about 80, and if it goes above 100, we think it abnormal; the patient is stronger and less nervous, and the respiration is normal."

Case 39.—A female, aged twenty-five, has suffered from Graves's disease for four years. Complains of nervousness, palpitation, and weakness; right exophthalmos marked. Treatment was begun on December 18, 1912, by two applications weekly of the X rays. On January 16, 1913, the X rays were replaced by radium, screened on all but one occasion by $\frac{1}{3}$ millimetre of silver; by the beginning of May a dose of 205 milligramme hours had been given. The patient's doctor, in July, 1913, said that she was much improved, especially the exophthalmos.

Case 40.—A female, aged fifty, ill for more than seven years with Graves's disease. Exophthalmos marked; complains principally of being awakened at night by attacks of breathlessness; cannot walk at all on this account; thyroid enlarged. Radium treatment begun on July 17, 1913, as a rule screened by $\frac{1}{3}$ millimetre of silver. In one month's time she had received 350 milligramme hours. In six weeks' time the patient showed considerable improvement; she could walk slowly for some distance (down to the shore and back—a mile altogether), whereas she had been confined to bed; but her principal relief was that she had quite lost the night attacks of breathlessness.

Case 41.—A male, aged fifty-three; duration of disease four years, with intermissions. Patient very ill, with a weak, irregular heart, dropsy of the legs, marked exophthalmos, and enlargement of the thyroid. Patient put on digitalis, and given a dose of 180 milligramme hours of radium in one week. Patient has gone home, but is being kept under observation; the thyroid was found in a months' time to be decidedly less.

Ionic Introduction of Radium.—Notwithstanding the great cost of the bromide of radium, attempts have been made by Haret, Fabre, and Lewis Jones to introduce radium by electrolysis into the body. The radium salt must be placed under the positive pole. Lewis Jones (" Ionic Medication," p. 94) describes his procedure as follows: " The radium solution is used to moisten a packet of ten or twelve filter-papers cut to the right size, and this is placed in contact with the

surface, and over this is placed a thick layer of lint or compressed cotton to form a cushion, which is moistened with tap-water. A trace of calcium is present in this, and helps to carry the current. A current of 5 milliampères for fifteen minutes is sufficient for an area of 15 square centimetres." Gout, rheumatoid arthritis, growths, and nævi have been treated with more or less success by this method.

Diseases of the Eye.—The advances that have been made in the treatment of diseases of the eye by radium we owe to Sir J. Mackenzie Davidson, who in his introductory address, as President of the section of Radiology, at the meeting of the British Medical Association in July, 1910, made the following remarks: " But if radium has not so far fulfilled all the hopes that were entertained of it, it has, at any rate, accomplished something, and it is encouraging to turn for a moment to a new field of experiment in which it has yielded good and definite results—namely, certain diseases of the eye. Here, again, the diseases in which it is potent are ' superficial.' So far as we have tried it in deep-seated diseases, the results are negative. On the other hand, in some external diseases of the eyes and eyelids, its action is very remarkable, and I feel sure that radium will take a high place in ophthalmic therapeutics. By way of example, I may instance five cases of spring catarrh which I have cured by radium. The first of these was cured four years ago, and there has been no recurrence. Some of these cases were extremely severe, and one of them, of over

six years' standing had undergone a great variety of treatment, both operative and otherwise, without any permanent benefit. And besides these, in cases of episcleritis, hypopyon ulcers (corneal ulcers generally), incipient keratitis and even in bad cases of pterygium, extraordinarily good results have been obtained."

Spring Catarrh.—Case 42.—A boy aged six, a patient of Dr. George Mackay's, was recommended to the Electrical Department of the Royal Infirmary, Edinburgh, on March 4, 1910, suffering from spring catarrh. Both upper lids were covered on their internal surface with the typical granulations and irregular, pavement-like blocks. The lids were much swollen. The disease had lasted some months (Fig. 38). It was decided, after consultation with Dr. Mackay, to treat the right upper lid only. At first an ebonite capsule with a mica window, containing 10 milligrammes of pure bromide of radium, was held as close, without touching, as possible to the everted lid for ten minutes a day. After a short time, as the boy attended as an out-patient, and could only come in once a week, more prolonged exposures by a relay of assistants were given. The radium was also enclosed in an aluminium box to avoid the risk of wetting it. Three or four weeks elapsed before any improvement could be observed, and then it was very slow, but steady. Owing to the demand for radium by more serious cases, a weak preparation containing 1 milligramme of the pure salt was substituted for the strong specimen. The boy was made to lie down,

PLATE XV.

FIG. 38.—SPRING CATARRH, TREATED AND UNTREATED.

and the glass tube containing the salt was fastened by plaster directly against the everted lid. On May 10, 1910, the right eye showed a great improvement, only one nodule being left; but the left or untreated eye was as bad as ever. At the end of June, as the right eye was practically well (Fig. 38), treatment of the left eye was begun. The right eye had received a total dose of 32·5 milligramme hours.

This case confirms Sir J. Mackenzie Davidson's results, and it would appear that in radium properly applied we possess a powerful remedy for spring catarrh.

Radium in Gynæcology.—Work has been done in the direction of treating metritis, salpingo-ovaritis, etc., and malignant disease of the uterus, by Wickham and Degrais, Cheron, Tuffier, and others. Mme. Fabre collected a series of cases under Broca, Cuneo, Oudin, and Cheron, where radium-therapy was employed, in which she claims that beneficial results were obtained. Professor Tuffier submitted some of his patients suffering from uterine cancer to radium treatment in the Beaujon Hospital. A glass tube containing 9 centigrammes of pure radium bromide, enclosed in a silver tube 1 millimetre thick, was placed inside a rubber drain-pipe, and introduced into the cancerous uterus. It was applied every sixth day, and left *in situ* for twelve hours at a time. The patient had been operated on eight months previously for cancer of the uterus; she now returned with a recurrence in the vaginal cicatrix and the foot of the

broad ligament. As a result of the treatment five-sixths of the pathological infiltration disappeared, but an induration persisted. In order to judge of the results obtained, sections were cut out of the tissue treated by radium, and from these Professor Tuffier draws the following conclusions, which are subject to modification:

1. The radiations penetrated to at least a depth of 2 centimetres.

2. The action of the radiations on the cancerous tissue was produced slowly; the absence of any morphological tissue modification for six or more days does not in any way imply that no action will follow later.

3. The action of the radiations was on the cancer cells and on the connective-tissue framework, but not equally; for the connective tissue was the less rapidly affected, the action being first and especially an elective one on the cancer cell.

Professor Tuffier compared these results with those produced by the X rays, and found that the latter were powerless in dealing with subcutaneous cancers; but in ulcerating, bleeding, and granulating tumours they exercised an incontestable hæmostatic action, causing cicatrization and producing an anæsthetic effect, but the healing was superficial and left the deep cancer intact. Microscopic examination of cancer treated by X rays showed that their action was specific on the cancer cell; there was an elective necrosis of the neoplastic elements. But this action was very limited as to depth, and that often in spite of apparent

cure. Active neoplastic elements were found at a depth of less than 2 millimetres from the surface treated; atrophied cells were found in the most superficial portions, but active cancer cells with karyokinesis were found in the subjacent layer (*British Medical Journal*, February 13, 1909).

In the First Annual Report of the Radium Institute, under the heading of *Carcinoma of the Uterus*, there are the following remarks: "In cases of inoperable malignant disease in this situation radium will often bring about results which cannot be attained by any other known method of treatment. The hæmorrhage is arrested, the discharge is diminished in amount and rendered inoffensive in character, the ulceration is healed, and the pain is greatly relieved. The rate of growth is checked, sometimes completely arrested, and the surrounding infiltration and induration are so much lessened that in a few instances cases previously declared to be inoperable become operable. The treatment is best carried out by the introduction of a tube containing 50 to 100 milligrammes of radium, screened with 2 millimetres of lead and 3 millimetres of rubber into the cervical canal; or, if this be not practicable, into the posterior fornix, a large, flat, strong applicator, screened by 2 millimetres of lead, being placed on the abdominal wall over the fundus of the uterus. The exposures should be prolonged, and from thirty to sixty hours' duration." (This dose would be about 3,000 milligramme hours.)

Eight cases are quoted, one of which is as follows:

"A patient, aged fifty-three, had hysterectomy (Wertheim's operation) performed on November 19, 1911, for carcinoma uteri. She made an excellent recovery, and kept well until the end of February, 1912, when recurrence took place in the upper part of the recto-vaginal septum. The condition was declared to be inoperable. She was seen on April 1, 1912. Examination *per rectum* revealed a definite ridge-like growth stretching transversely across the recto-vaginal septum 5 centimetres from the anal orifice. She was treated with two tubes of radium containing 75 milligrammes, and screened with 1·5 millimetres of lead, one tube being placed in the rectum and one in the vagina; she had in all twenty hours' treatment." (This dose amounted, if the 75 milligrammes was shared between the tubes, to 1,500 milligramme hours; but if each tube contained 75 milligrammes, the dose would be 3,000 milligramme hours.) "She was examined by her surgeon on June 7, who reported that all trace of the growth had disappeared, and that the patient looked and felt perfectly well. At the end of October (four months later) she wrote to say she was in excellent health." Favourable reports also continue to come from the Continent.

At a meeting of the Société Médicale des Hôpitaux of Paris on July 28, 1911, Rubens Duval and H. Cheron communicated an important paper on the treatment of inoperable cancer of the cervix uteri by the more penetrating rays of radium (*Lancet*, October 28, 1911). In general great amelioration was obtained, and in

some cases the lesions cicatrized, and the patient recovered apparently perfect health, which was maintained for several months. Some of the results were possibly cures. More cogent than the clinical evidence was the microscopic examination of nine specimens. Two were removed post mortem, and seven by hysterectomy from patients in whom the disease, at first inoperable, under radium regressed sufficiently to become operable. Four of these showed zones of epithelioma regressing, characterized by the destruction of the cancerous cells under the influence of the radium rays. Five showed complete absence of cancer in the uterus, vagina, and the broad ligaments. In the other three the absence of cancer in the cervix contrasted with the persistence of a focus in the body of the uterus near the isthmus. The possibility of such foci, which in consequence of their distance cannot be influenced by radium, shows that apparent cure of cancer of the cervix by radium must not be relied upon, but that as soon as the case becomes operable hysterectomy should be performed. The following case is an example of how an inoperable case may be rendered operable: " A woman, aged forty-seven, was sent to Dr. Lejars at the end of 1908 with a large epithelioma of the cervix extending into the anterior fornix, and complicated by peri-uterine infiltration. The case appeared to be inoperable. Three applications of radium were made at intervals of a month. On each occasion an apparatus containing 5 centigrammes was left in the cervical cavity for twenty hours. (Each dose would amount

to 1,000 milligramme hours.) A fortnight after the last application the fornices were much more supple, and the cervix had diminished in size, and I was able to operate. I performed total abdominal hysterectomy. The patient recovered, and remained in good health for a year. Then recurrence occurred." Wickham and Degrais, in their new volume, "Le Radium," published in 1913 (p. 63), speak strongly regarding the value of radium in cancer of the uterus. It is, they say, in the treatment of cancer of the uterus that radium perhaps plays its most useful and interesting rôle. Thanks to the small size and form of the containers, they can be introduced into the uterine canal, and can be kept in place for a long time very easily. Sometimes in advanced cases and in thin subjects it may be well to apply at the same time a radium apparatus on the abdomen so as to obtain a crossed fire. As Dr. Jacobs has well remarked, it is with a true scientific emotion that the neophyte observes, in the case of an inoperable cancer of the cervix, the distinct regression of the local and general signs of the disease. Ulcerations dry up, vegetations disappear, hæmorrhages and discharges cease, the fœtid smell diminishes, the pain grows less, and a sclerotic tissue appears and takes the place of the lesions. Still, the use of radium is only a palliative method.

At the London meeting of the International Medical Congress, held in August, 1913, various speakers dealt with the action of radium and mesothorium in gynæcology. Dr. Foveau de Courmelles (Paris) described

his method of introducing aseptic tubes of radium (5 centigrammes as a minimum) for twenty-four hours, and to repeat the applications monthly. (Such a dose would amount to 1,200 milligramme hours.) In malign tumours his personal statistics included 100 inoperable cases, seventy of which had shown ameliorations lasting from one to four years.

Professor Paul Kroemer (Greifswald) referred to the action of mesothorium. In his total of thirty-two cases he had had favourable results in rectal, vaginal, and uterine growths, but not in ovarian. Photomicrographic records of his cases both before and after treatment were exhibited. An interesting case was that of a metastasis in the vulva, which was cured clinically by an injection of thorium X. Professor Jacobs (Brussels) (*British Medical Journal*, August 23, 1913) said that the results he had obtained by the employment of radium in massive doses in uterine and vaginal cancers — many of the cases being relapses after operations—led him to the conclusion that this was a most desirable treatment. He used two tubes of radium (12 to 20 centigrammes), keeping them in the tumour for twenty-four or thirty-six hours, or even for forty-eight hours, and repeating these applications every ten or twelve days during four or five weeks. (Each dose would amount to between 5,000 and 6,000 milligramme hours.) There is no reference to the screen employed in the Report, but even if a 2 millimetre lead screen were used, the dose is a larger one than it has been hitherto customary to administer

without an intermission. In the case, No. 43, of a large ulcerating epithelioma of the back of the knee (Figs. 39 and 40), for which amputation had been recommended, the author has administered a dose of 8,400 milligramme hours, spread over a fortnight, screened only by $\frac{1}{3}$ millimetre of aluminium, with marked benefit. The ulcer, which measured $3\frac{1}{2}$ inches wide by $4\frac{1}{2}$ inches long, and was deeply excavated, has now almost completely skinned over. He (Professor Jacobs) had submitted to this heroic treatment more than twenty-four cases of cancer of the uterine neck, and all had been favourably influenced. The cases were not of sufficient duration for him to speak definitely of cure, but in three of which he gave detailed accounts, the women being respectively forty-four, thirty-nine, and seventy years of age, the lesions had shown no tendency to recur in from two to three and a half years. For some reason cancer of the external genital organs did not retreat so well under this treatment; perhaps the quantity of radium employed was insufficient.

Dr. Robert Abbe (New York) described some experiments he had carried out with wheat and narcissus bulbs and seeds. After exposure at different distances to a constant radium radiation, he found a threefold influence. First, a death-dealing force exerted on the seeds in closest proximity; secondly, a stimulating effect upon those placed at a little distance; thirdly, a depressing and retarding effect upon the seeds situated at a still greater distance—several inches from the radium—within the range only of the gamma rays. This gamma

PLATE XVI.

FIG. 39.—EPITHELIOMA FOLLOWING LUPUS, BEFORE TREATMENT.

Ulcer measured $3\frac{1}{2}$ by $4\frac{1}{2}$ inches, and was deeply exeavated.

FIG. 40.—EPITHELIOMA FOLLOWING LUPUS, AFTER PARTIAL TREATMENT.

Ulcer measures $\frac{1}{2}$ ineh by $2\frac{3}{4}$ inches, and has filled up.

radiation was of immense importance to surgery. It was responsible for bringing about a retrograde change and depression in those cells of erratic overgrowth and life-destroying qualities. He had noticed that these phenomena had their analogy in the human body: tissues too closely in contact had been destroyed, pathological tissues a little farther removed had been stimulated, while those still farther away had, given a proper dosage, undergone a retrograde degeneration, amounting at times to surgical cure. In the field of uterine cancer there was good hope, and it was certain that the immediate effect of energetic radium treatment on cancer developed in the cervix or in the scar after operation was to modify profoundly the condition and give a sound cicatrix. The specific action of radium was remarkably illustrated in the case of sarcomas, particularly giant-celled sarcomas of bone. Radium could also cure X-ray lesions; he had removed epitheliomas from the hands of an X-ray operator by its means.

Rheumatic Conditions — Use of Radio-active Earths.—Reference has already been made (p. 31) to the production and use of the emanation. It can also be administered by the employment of radio-active earths. One of the best known of these is obtained in the process of uranium extraction; it contains certain oxides of iron, aluminium, uranium, and manganese, and traces of actinium, radium, and polonium. Of the latter, actinium is the most important. Pure actinium is estimated by some

physicists* to be ten times as radio-active as radium; the quantity present in the earth suffices to confer upon it a radio-activity of 0·15 as compared to 2,000,000 in the case of radium.

The following is a table of comparative radio-activities (Claude):

Actinium	(about)	20,000,000
Radium ..	,,	2,000,000
Uranium ..	..	1
Earth ..	..	0·15

One centigramme of the earth spread over one square centimetre yields a radiation about one-seventh the strength of that of uranium. The earth is an extremely weak radio-active preparation, which yields alpha, beta, and gamma rays, and an emanation. It is, however, relatively to radium, very cheap, a kilogramme costing thirteen shillings.

The earth has been employed for some time by Dr. Claude and others in the hospitals of Paris in the treatment of arthritis deformans, subacute and chronic rheumatism, and gonorrhœal rheumatism, also for neuralgia and certain cutaneous (pruritus) and gynæcological affections.

The affected joint having been cleansed, the moistened earth is spread in the form of a compress around it, and maintained in position by a piece of

* Pure actinium has not been isolated, but it is believed that it would show an aetivity eomparable with that of radium (Rutherford).

oil-silk and a bandage. It must not be allowed to become dry. No emanation would be given off if it became dry. The plaster can be left on all night, and applied on alternate nights for ten days.

It should always be remoistened and made quite plastic and soft before application. It does not lose its strength. In some cases it may be advisable to sterilize it by heat (open sores, introduction into the cavities of the body); this will not affect its activity.

Dr. Guyenot (*Lancet*, October 15, 1910) prepares a radio-active earth or mud by mixing powdered pitch-blende with twice its volume of hot water. This is applied direct to the part to be treated, and can be left on several hours under a piece of waterproof. This mud exercises a sedative effect, and is believed to promote the absorption of exudations. It does not irritate the skin, its radio-activity is permanent; but when it has been used, it must be allowed to dry for a fortnight before it is used again.

Another method of employing the earth is to make use of baths. Two hundred and fifty grammes of the earth are mixed with the warm water of the bath; more may be used if desired, but this is the usual strength. The patient can remain in the bath for half an hour, and have a series of a dozen in a fortnight or longer.

Good results are claimed to have been obtained by Claudé and Teulière (*Brit. Med. Journ.*, March 12, 1910) in arthralgia and subacute forms of arthritis.

The pain, redness, and swelling, usually disappear with great rapidity, but affections of the lower limb appear to be more rebellious than those of the upper limb. The best results appear to have been obtained in subacute gonorrhœal rheumatism.

Mud baths have been for a long time in vogue at certain health resorts; it is possible that the beneficial results may have depended upon the presence of traces of radio-active substances. The same may be said of certain mineral waters.

General Comparison between X-Ray and Radium Treatment.—Whether there is any specific therapeutic difference between X-ray, and radium radiations is a question not yet settled. I have observed that certain rodent ulcers, particularly those situated in the furrow between the ala nasi and the cheeks, which were refractory to X rays yielded rapidly to radium; but apart from this both methods have relative advantages and disadvantages.

The gamma rays of radium are far more penetrating than X rays; Tuffier found their effect manifest on the tissues at a depth ten times as great as that of X rays. Hence they are to be preferred for deep-seated affections (syringomyelia, subcutaneous cancers, tuberculous glands, etc.). Radium rays are perfectly " constant " in quantity and quality as opposed to X rays, of which one may say, " Varium et mutabile semper "; hence a dose of radium rays can be measured with a precision that is wanting in the case of the X rays. Radium can be placed in natural cavities or buried

in tumours, and left for an indefinite period, giving off its radiation all the time. The quality of the reparation tissue left after radium treatment leaves nothing to be desired, and is superior to that following X-ray treatment. So perfect is the scar after treatment with radium that it is sometimes difficult to find the site of the previous lesion. Radium dermatitis is not so painful or intractable as X-ray dermatitis. Radium is readily portable from patient to patient, and can be left to be applied by others after instruction.

Against these advantages is to be set the very great disadvantage of its extremely high price. To this must be added the risk of loss by breakage or accident. The chief advantages of the X rays over radium is the large area to which the former can be applied.

It was hoped that mesothorium, which was considerably cheaper than radium, might to some extent replace the latter, but during the past year mesothorium has doubled in price, and is now quoted at £15 a milligramme against £20 for radium. The period of mesothorium is only about one-hundredth that of radium.

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